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**National Highway
Traffic Safety
Administration**

NHTSA

DOT HS 813 127

May 2021

Special Crash Investigations: On-Site Guardrail End Terminal Crash Investigation; Vehicle: 2005 Dodge Dakota; Location: Missouri; Crash Date: June 2018

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15. Supplementary Notes

Each crash represents a unique sequence of events, and generalized conclusions cannot be made concerning the crashworthiness performance of the involved vehicle(s) 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.

16. Abstract

This report documents an on-site investigation of a pickup truck impact to a sequential kinking terminal guardrail end terminal that is of interest to the Federal Highway Administration (FHWA). This investigation was conducted on behalf of the FHWA. This single-vehicle crash involved a 2005 Dodge Dakota equipped with dual-stage frontal air bags. The crash occurred in June 2018 at night in Missouri on the east roadside of a four-lane, divided, interstate highway. A belted 56-year-old male drove the vehicle, which departed the east side of the roadway and struck a road sign. The vehicle continued northbound on the roadside for approximately 105 m (344 ft) and the right plane struck the end terminal of a blocked-out W-beam guardrail, damaging the guardrail and five posts. The vehicle returned to the roadway and the driver continued traveling north for approximately 3 km (2 miles). He was stopped by the investigating police officer. The driver sustained police reported "C" (possible) injuries and was transported by ambulance to a local hospital, where he was treated in the emergency room and released.

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TABLE OF CONTENTS

Special Crash Investigations
On-Site Guardrail End Terminal Investigation
SCI Case No: IN18009
Vehicle: 2005 Dodge Dakota
Location: Missouri
Crash Date: June 2018

Background

This report documents an on-site investigation of a pickup truck impact to a sequential kinking terminal guardrail end terminal that is of interest to the Federal Highway Administration (FHWA). This investigation was conducted on behalf of the FHWA. This crash was identified by an engineer with the Missouri Department of Transportation, who submitted images of the vehicle and the damaged guardrail end terminal to the FHWA. The FHWA determined that the guardrail end terminal and crash type were of interest for further research. This crash investigation was then initiated by the National Highway Traffic Safety Administration in June 2018 and assigned to the Special Crash Investigations (SCI) team at the Indiana University Transportation Research Center. This single-vehicle crash involved a 2005 Dodge Dakota pickup truck (Figure 1). The crash occurred in June 2018 at night in Missouri and was investigated by a local police agency. The guardrail and crash site were inspected in June 2018. A telephone interview with the driver was conducted in September 2018.

Figure 1. Right side view of the Dodge.

This crash occurred on the east roadside of a four-lane, divided, interstate highway. The Dodge was a quad-cab (4-door) pickup truck equipped with dual-stage frontal air bags. A belted 56-year-old male drove the vehicle northbound in the right lane of the interstate that curved to the right. The vehicle departed the east side of the roadway and struck a road sign. The vehicle continued northbound on the roadside for approximately 105 m (344 ft) and the right plane struck the end terminal of a blocked-out W-beam guardrail, damaging the guardrail and five posts. The vehicle returned to the roadway and the driver continued traveling north for approximately 3 km (2 miles). He was stopped by the investigating police officer. The driver sustained police reported "C" (possible) injuries and was transported by ambulance to a local hospital, where he was treated in the emergency room and released.

Crash Summary

Crash Site

This crash occurred at night on the east roadside of an unlighted, four-lane, divided, interstate highway. The weather conditions at the time of the crash were cloudy with 16 km (10 miles) visibility, southeast winds at 13 km/h (8 mph), a temperature of 22.7 °C (73 °F), and a dew point of 13.3 °C (56 °F), according to the local weather reports. The roadway curved to the right and had two bituminous northbound lanes that were separated from the southbound lanes by a concrete Jersey barrier (Figure 2). The calculated radius of curvature was 3,077 m (10,093 ft). The superelevation was +2%. The travel lanes were approximately 4 m (13 ft) wide and were bordered by 1.7 m (5.6 ft) and 2.4 m (7.9 ft) wide bituminous shoulders on the west and east, respectively. Pavement marking consisted of a broken white lane line, a solid white east edge line and a solid yellow left edge line. Rumble strips were cut into the east shoulder. On the approach to the crash site, the east roadside was grass surfaced that transitioned to a shallow drainage ditch. A road sign mounted on two multi-directional breakaway slipbase posts was located in the grass roadside. A blocked-out W-beam guardrail equipped with an SKT end terminal was located along the east roadside and protected northbound traffic from an overpass. The posted speed limit was 113 km/h (70 mph). A crash diagram is included at the end of this report.

Figure 2. Northbound view of the roadway.

Pre-Crash

The Dodge was traveling north in the right lane as the driver was negotiating the right curve. The driver stated during the interview that he intended to take the exit prior to the crash site but missed the exit and continued to travel on the roadway. The driver stated to the investigating officer, “I just took a drink of strawberry kiwi water and then I just went off the road.” The Dodge drifted to the right and traversed the rumble strip and the east shoulder before entering the east roadside in a tracking mode. The departure angle was approximately 3- to 5 degrees. The Dodge continued in a northerly direction on the roadside for approximately 68 m (223 ft). Due to the slope of the roadside and a counterclockwise steering input by the driver, the Dodge initiated a slight counterclockwise yaw approximately 15 m (49.2 ft) prior to the impending impact with the highway sign.

Crash

The Dodge struck the roadside sign mounted on two round posts, each with a breakaway slip-base attachment (Figure 3). The front plane right aspect struck and separated the left post (Event 1) and the right plane struck the right post (Event 2). The force direction for both events was in the 12 o'clock sector. The damage algorithm of the WinSMASH program could not be used for either event since yielding objects are out of scope for the program. However; the barrier equivalent speed (BES) algorithm of WinSMASH was used to calculate a BES of 14 km/h (8.7 mph) for Event 1. The right plane impact (Event 2) was a sideswipe with overlapping damage. WinSMASH could not be used for this impact due to the overlapping damage from the guardrail terminal head impact.

Figure 3. North approach to the sign posts impacts.

The vehicle continued northwest on the roadside for approximately 105 m (344 ft) as the driver began to steer the vehicle left, back toward the roadway. The Dodge yawed counterclockwise on the approach to the field side of the end terminal. Immediately prior to the guardrail impact, the driver steered back to the right as he was about to reenter the northbound travel lanes. The right front tire and wheel struck the end terminal and displaced the end terminal from post 1 and further displaced the terminal head along the W-beam. As the Dodge reentered the east shoulder, the front right undercarriage overrode the base of post 1 and struck post 2 causing damage to the undercarriage. The right plane struck the end terminal and extruded 4.4 m (14.4 ft) of guardrail to the field side, kinked the W-beam at two locations (Event 3, Figure 4), and damaged a total of 7.8 m (25.6 ft) of guardrail and five guardrail posts. WinSMASH could not be used for this event since yielding objects are out of scope for the program and there was no damage to the front bumper from this impact. Furthermore, there was overlapping damage from the right-side post impact. None of the air bags deployed during the crash sequence.

Figure 4. North-facing overhead view of the damaged guardrail.
(Post 1 reinserted to pre-crash location)

Post-Crash

The vehicle returned to the roadway after the impact with the guardrail system. The driver continued without stopping to travel north for a police-reported distance of approximately 3 km (2 mi). The investigating officer of this crash observed the Dodge traveling on the interstate without its right front tire and stopped the vehicle. The driver of the Dodge brought the vehicle to a controlled stop on the right shoulder. The officer questioned the driver and requested ambulance and tow assistance. The driver exited under his own power through the left front door and was transported by ambulance to the emergency room of a local hospital, where he denied injury and was released. The driver did report four minor injuries during his interview. The vehicle was towed due to damage to a local tow yard, where it was inspected for this investigation.

End Terminal and Guardrail Damage

The right front tire and wheel of the Dodge initially struck the SKT end terminal as the driver attempted to return to the travel lanes. The angle of impact originated from the field side of the guardrail. The end terminal head measured 50 cm (19.7in) wide and 51 cm (20.0 in) high and sustained minor damage to the protruding flange (Figure 5). Initially, post 1 became detached from its hinged base. The SKT end terminal extruded 4.4 m (14.4 ft) of guardrail toward the field side. The guardrail separated from post 2 as the undercarriage of the Dodge overrode the post that collapsed downstream to the ground from its pivot base. Post 3 was displaced downstream approximately 20 degrees off vertical and its composite offset block, as well as the guardrail became detached. Post 4 remained upright but detached from the guardrail and composite offset block. Post 5 remained upright but rotated clockwise approximately 20 degrees and remained bolted to the composite offset block and guardrail. Post 6 to 12 were undamaged and remained attached to their composite offset blocks and the guardrail. The total length of the damaged guardrail was 7.8 m (25.6 ft). The guardrail kinked 180 degrees at post 4 and approximately 30 degrees at post 5 **(**Figure 6**)**. The FHWA Guardrail Form is attached to the end of this report in the Appendix.

Figure 5. Southerly view, impact face. (Note - vertical tire tread)

Figure 6. Northerly view, extruded and kinked guardrail.

2005 Dodge Dakota

Description

The Dodge Dakota was a 4-door quad cab pickup truck manufactured in September 2004 and was identified by Vehicle Identification Number 1D7HW58N35Sxxxxxx. The specified wheelbase was 333 cm (131 in). Specifications listed the powertrain with a conventionally mounted 4.7-liter, V-8 engine linked to a 5-speed automatic transmission with a column-mounted selector lever and 4-wheel drive. The 4-wheel drive system was electronically controlled by a switch on the instrument panel. The service brakes were power-assisted front disc/rear drum with ABS. The gross vehicle weight rating was 2,727 kg (6,010 lb) with gross axle weight ratings of 1,633 kg (3,600 lb) for both axles. The vehicle manufacturer's recommended tire size was P265/65R17 with cold tire pressures of 240 kPa (35 PSI). The vehicle was equipped with Goodyear Wrangler SR-A tires on the left side and right rear wheels of the recommended size. They were in good condition and were not damaged in the crash. The right front tire separated during the crash and was missing at the time of the SCI inspection.

The interior of the Dodge was configured for seating of five occupants (2/3) with front row bucket seats and a split-bench second row seat with a folding back. All seating surfaces were vinyl. The front row and second row left and right positions were configured with adjustable head restraints. Both front row head restraints were in the full-down positions. Safety systems consisted of manual 3-point lap and shoulder belts and a center rear lap belt and a Certified Advanced 208-Complaint frontal air bag system with front row retractor pretensioners. None of the air bags deployed and the pretensioners did not actuate.

Exterior Damage

The Dodge sustained minor severity damage to the right aspect of the front bumper from impact with the left break-away sign post. The direct contact damage to the front bumper fascia (Figure 7) began 43 cm (16.9 in) left of the right front bumper corner and extended 17 cm to the right. Crush measurements were documented along the bumper profile and yielded a maximum crush of 3 cm (1.2 in), located 28 cm (11.0 in) right of the vehicle's centerline. The compression of the bumper fascia against the bumper beam and mounting bracket produced a semi-circular punch out-type cut to the fascia. A matching transfer was present on the struck post. The Collision Deformation Classification (CDC) for this event was 12FZLN1 (10 degrees).

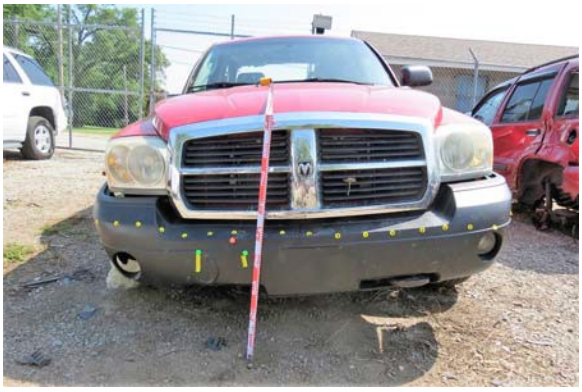


Figure 7. Front plane impact to the sign post.

The right plane of the Dodge struck the right break-away sign post. The initial contact involved the right outside rear view mirror. The mirror was separated from the window frame mounting point. Sideswipe-type damage began on the trailing edge of the right front door at the beltline area and continued onto the right rear, window frame, C-pillar, and the leading edge of the cargo box. The severity of this impact damage was minor due to the break-away type post. This area of damage was subsequently struck by the deformed guardrail which overlapped and masked the post-impact damage. The estimated CDC for the Event 2 damage was 12RYAS2.

As the Dodge approached the end terminal, it was in a slight counterclockwise yaw. This exposed the aft aspect of the tire and wheel to the face of the end terminal at impact. The end terminal impact fractured the wheel rim and the right undercarriage (Figure 8) of the Dodge struck and overrode the base of post 1 and post 2. The aft portion of the lower control arm fractured and the right frame rail and sway bar were gouged. Undercarriage protective shields and the washer fluid container were contacted and fractured.

Figure 8. Undercarriage damage from the guardrail posts.

As the Dodge progressed forward, its engagement with the end terminal in conjunction with the driver's clockwise steering maneuver reversed the Dodge's yaw from counterclockwise to clockwise. The right plane of the Dodge contacted the displaced end terminal, compressed the end terminal, and kinked the W-beam in a northerly direction. This impact damage overlapped the damage from the Event 2 post and involved the right rear door, C-pillar, and the cargo box. In the overlapping damage patterns were horizontal creases from the deformed guardrail, snagging at the midpoint of the door window frame gasket and trailing edge of the window frame. The C-pillar was crushed and rolled rearward and the leading edge of the cargo box was crushed laterally and rearward (Figure 9). The direct damage began 178 cm (70.1 in) forward of the right rear axle and extended 135 cm (53.1 in) forward. Crush measurements were documented at the mid-door level and the maximum crush was 6 cm (2.4 in), occurring on the right rear door located 76 cm (29.9 in) forward of the right rear axle. The CDC for the event damage was 01RDEW2.

Figure 9. Overlapping right plane damage to the Dodge from the sign post and end terminal.

Event Data Recorder

Due to its date of manufacture, the Dodge was not equipped with an event data recorder supported by the Bosch Crash Data Retrieval tool.

Interior Damage

The interior of the Dodge sustained minor damage from intrusion. The right B-pillar and the rear upper panel of the right rear door intruded laterally 14 cm (5.5 in) and 9 cm (3.5 in), respectively. Inspection of the vehicle's interior revealed no discernable evidence of occupant contact.

Manual Restraints

The Dodge was equipped with 3-point lap and shoulder continuous loop seat belts for the front and second-row left and right positions. The second-row center position was lap-belt-equipped. Both front row seat belts were configured with sliding latch plates and adjustable D-rings. Both front row D-rings were adjusted to the full-down positions. The driver's seat belt retracted onto an emergency locking retractor (ELR) while the front-row right and second-row left and right positions used switchable ELR/automatic locking retractors (ALR). Both front row retractors were configured with pretensioners.

The driver stated he was restrained by the manual seat belt system at the time of the crash. He also reported during the interview a contusion on his abdomen from the seat belt. There were no discernable load marks on the seat belt webbing, latch plate, or D-ring, or evidence of occupant loading. The pretensioners did not actuate in this crash.

Supplemental Restraints

The Dodge was equipped with Certified Advanced 208-Compliant driver's and passenger's frontal air bags and retractor pretensioners. The system consisted of dual-stage frontal air bags, seat-track-positioning sensors, a right-front-occupant-classification sensor with a low-risk deployment right front air bag. The driver's frontal air bag was mounted in the four-spoke steering wheel rim with an I-configuration module cover. The passenger's frontal air bag was a top mount design in the right instrument panel. There was no air bag deployment as a result of the crash.

2005 Dodge Dakota Occupant

Driver Demographics

Age/sex:	56 year old/male
Height:	160 cm (63 in)
Weight:	98 kg (215 lb)
Eyewear:	Glasses
Seat type:	Bucket
Seat track position:	Middle
Manual restraint usage:	Lap and shoulder belt
Usage source:	Injury data
Air bags:	Frontal; not deployed
Alcohol/drug involvement:	None
Egress from vehicle:	Exited under own power
Transport from scene:	Ambulance
Medical treatment:	Treated and released

Driver Injuries

Injury No.	Injury	Injury Severity AIS 2015	Involved Physical Component (IPC)	IPC Confidence Level
1	Upper front tooth fracture	251404.1	Steering wheel rim	Certain
2	Lower lip laceration	210602.1	Steering wheel rim	Certain
3	Abdominal contusion	510402.1	Lap belt	Certain
4	Left shoulder strain	740602.1	Shoulder belt	Certain

Source: Driver interview. Emergency Room records did not list any injuries.

Driver Kinematics

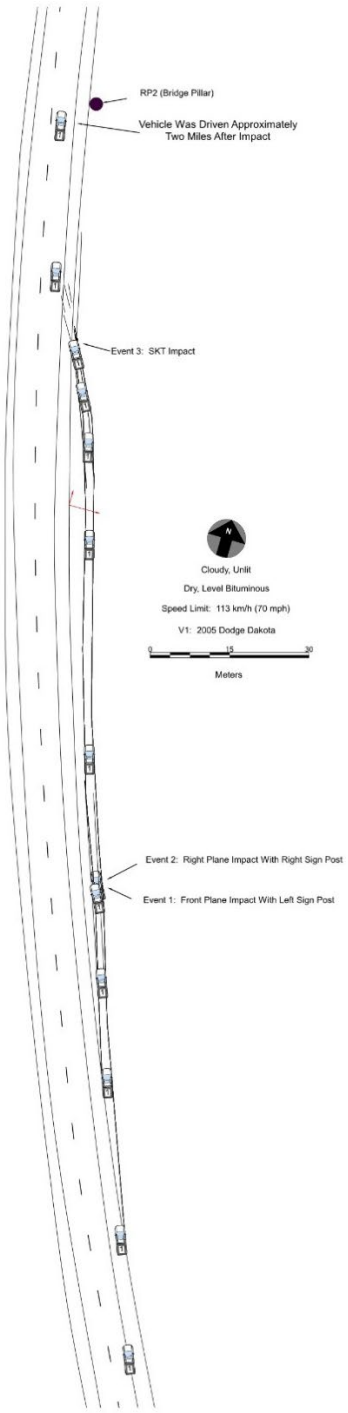
The driver was seated in an upright driving posture with the seat track adjusted to the middle position. The seat back was in a normal reclined position with the adjustable head restraint in the full-down position. He stated he was restrained by the lap and shoulder seat belt. There was no direct loading evidence on the seat belt system to support usage, yet injury data indicated that the driver was restrained.

The front and right plane impacts with the sign posts minimally displaced the driver forward and slightly to the right. He would have loaded the seat belt system that prevented him from interior contact. The Event 3 impact with the end terminal displaced the driver forward. He would have loaded the seat belt system. His loading force on the seat belt resulted in strain of the left shoulder and an abdominal contusion. The driver's head flexed forward and struck the steering wheel rim resulting in a laceration of the lower lip and a fractured tooth.

The end terminal impact did not deploy the driver's frontal air bag. Furthermore, the vehicle did not come to final rest at the crash scene. The Dodge reentered the northbound lane and the driver continued to travel toward his destination. An on-duty police officer spotted the vehicle with a

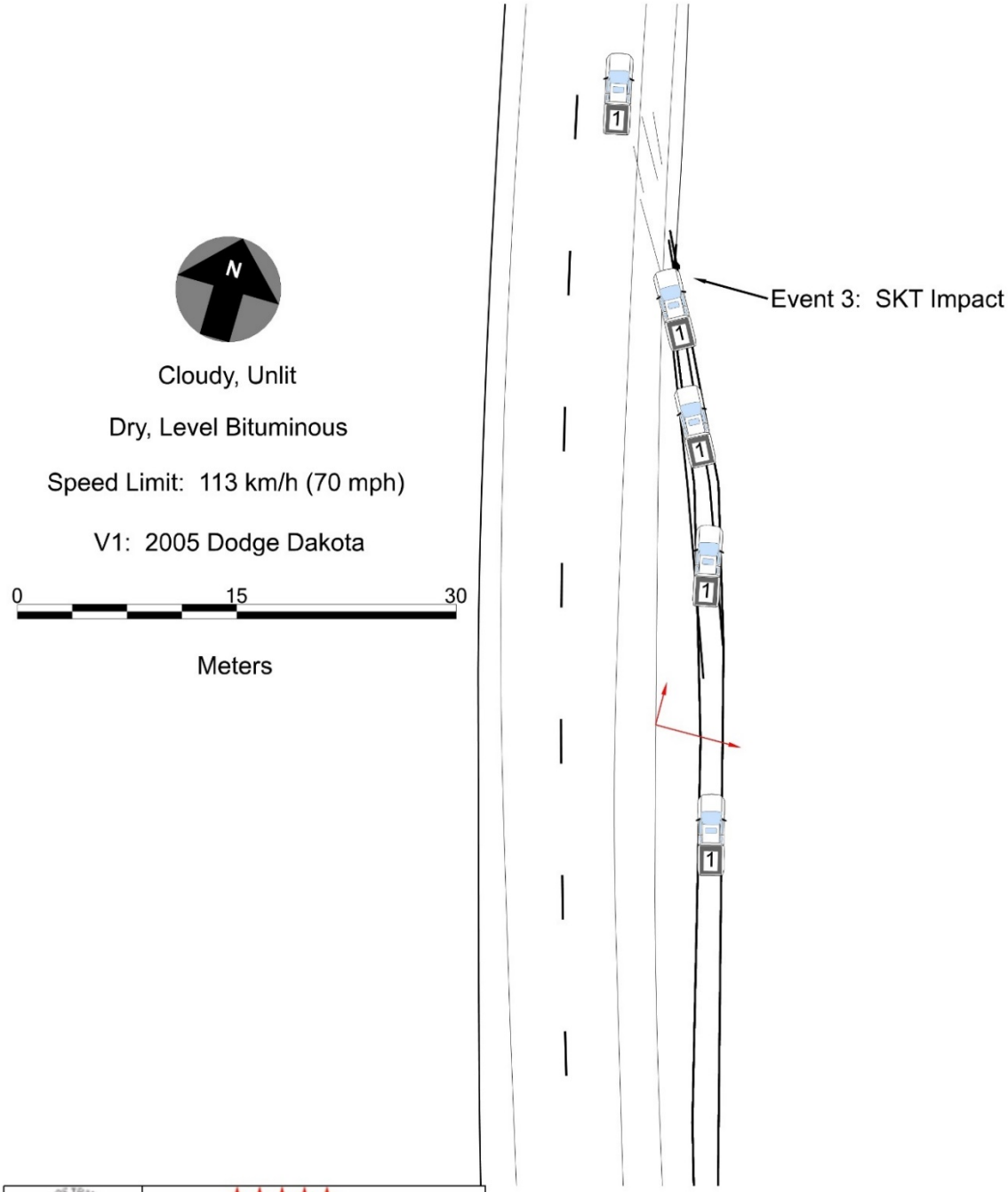
disabled right front tire and wheel and conducted a routine traffic stop. The police officer requested the driver to be transported by ambulance to a hospital for evaluation. The driver was not cooperative with the medical staff and was released without documentation of injury. The injuries identified above were obtained from the driver interview.

Crash Diagram



	www.nhtsa.gov
Case Number:	IN18009

Crash Diagram (Focused View of Guardrail Impact)



Appendix A: FHWA Guardrail Form

Case No.: IN18009

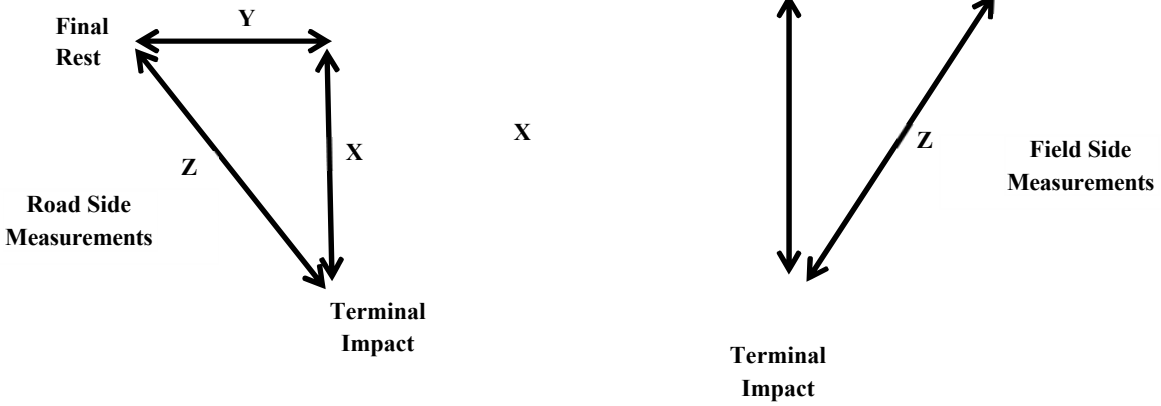
PREPOPULATED DATA (BY OTHERS)			
Date of Crash	June 2018	**TIME OF CRASH**	Nighttime
Case Number	IN18009	**State**	MO
Traffic Route	I-29	**Direction (Southbound = SB)**	NB
Ambient Conditions (at time of crash)			
Temperature (°F)	73 °F	**Lighting**	Dark
Atmospheric	Cloudy		

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 = N/A
Est. distance (longitudinal) along guardrail from terminal impact to COM final resting location (ft.)	X = N/A
Est. distance (normal) from either 1. the white paint line; or 2. roadway/shoulder/pavement edge to COM rest position (ft.)	Y = N/A
Super elevation	☑+2% ❒-2% ❒ NONE or FLAT
Curve Radius (ft.)	3077

KEY:

COM - Center of Mass of Vehicle

Distance Measurements



Case No.: IN18009

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									
1	Steel	6x6	N/A	N/A	Unknown	N/A	9.8		6’0”
2	Steel	6x4	N/A	N/A	Unknown	N/A	9.7		6’4”

Case No.: IN18009

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.)					
3	Steel	6x4	Comp	Unk	Unknown	N/A	10.1		6’2”
4	Steel	6x4	Comp	Unk	Unknown	N/A	10.0		6’4”
5	Steel	6x4	Comp	8x4	No	N/A	10.0		6’3”
6	Steel	6x4	Comp	8x4	No	N/A	9.8		6’3”
7	Steel	6x4	Comp	8x4	No	N/A	9.9		6’2”
8	Steel	6x4	Comp	7.75x4	No	N/A	9.6		6’4”

Case No.: IN18009

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	6x4	Comp	8x4	No	N/A	9.4		6’4”
10	Steel	5.5x4	Comp	8x4	No	N/A	9.3		6’0”
11	Steel	6x4	Comp	8x4	No	N/A	9.0		3’3””
12	Steel	6x4	Comp	8x4	No	N/A	9.0		3’3”

Additional Comments

Case No.: IN18009

EXTRUDER			
Feeder Channel Width at impact head	☑4inches ❒5 inches ❒Other_____		
Guide Chute Exit Height (in.)	20”		
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.)	14’4”
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.]	25’		

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

ALL-SYSTEM PERFORMANCE		
Railkinks Downstream of Head?	❒No	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 1**	**At Post 1**	**50 ft Past Post 1**
Percent - %	-32.5	-43.7	Level
Adjacent Lane Width (ft)	11’ 9”		
Lane Type (NAS EDS Variable: Sur. Type)	Bituminous		
Shoulder Type	Bituminous		
Shoulder Width (ft)	102”		
Guardrail Height (in)	25”		

Case No.: IN18009

VEHICLE INFORMATION		
Vehicle Type (NHTSA Input)	2005 Dodge Dakota	
Vehicle Identification Number (VIN)	1D7HW58N35Sxxxxxx	
Vehicle Mass (NASS var.: veh.wgt.)	3233 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	01RDEW2	
Delta-V	Unknown (Yielding object)	
Occupant Compartment Penetration of rail	☑No	❒Yes; Describe: (HEAD…intruded)
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)		
Rollover Type, Terhune Scale, (NASS EDS variable: rolintyp)		

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U.S. Department
of Transportation

**National Highway
Traffic Safety
Administration**

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