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National Highway Traffic Safety Administration

NHTSA

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Special Crash Investigations: On-Site Guardrail End Terminal Crash Investigation; Vehicle: 2003 Nissan Maxima; Location: Missouri; Crash Date: May 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 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.

16. Abstract

This report documents the on-site investigation of a passenger vehicle impact to a sequential kinking terminal guardrail end terminal of interest to the Federal Highway Administration (FHWA). The investigation was conducted on behalf of the FHWA. The single-vehicle crash involved a 2003 Nissan Maxima equipped with frontal air bags. Due to its date of manufacture, the vehicle was not equipped with an Event Data Recorder supported by the Bosch Crash Data Retrieval tool. The crash occurred in May 2018 at night in Missouri on the north roadside in the gore of a four-lane, divided, interstate highway interchange. A belted 19-year-old male drove the Nissan in a westerly direction in an unknown lane. The Nissan departed the right side of the roadway, and, as the driver steered to the left, the vehicle began to rotate counterclockwise. The right plane struck and fractured the break-away base of a luminaire (Event 1) and then struck the end terminal of a blocked-out W-beam guardrail (Event 2). The vehicle came to final rest, engaged with the end terminal that intruded into the front-row right position of the occupant compartment. The Nissan's driver sustained police-reported "B" (non-incapacitating) injuries and was transported by ambulance to a hospital, where he was treated and released.

17. Key Words sequential kinking terminal, end terminal, W-beam guardrail road departure, intrusion, non-incapacitating injury	18. Distribution Statement The document is available to the public from the National Technical Information Service, www.ntis.gov.

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Special Crash Investigations
On-Site Guardrail End Terminal Investigation
Case Number: IN18008
Vehicle: 2003 Nissan Maxima
Location: Missouri
Crash Date: May 2018

Background

This report documents an on-site investigation of a passenger vehicle impact to a sequential kinking terminal (SKT) guardrail end terminal 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 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 May 2018 and assigned to the Special Crash Investigations (SCI) team at the Indiana University Transportation Research Center. The investigation was conducted on behalf of the FHWA. This single-vehicle crash involved a 2003 Nissan Maxima (Figure 1) equipped with frontal air bags. Due to its date of manufacture, the vehicle was not equipped with an Event Data Recorder supported by the Bosch Crash Data Retrieval tool. The crash, which occurred in May 2018 at night in Missouri, was investigated by a local police agency. The vehicle, guardrail, and crash scene were inspected in May 2018.

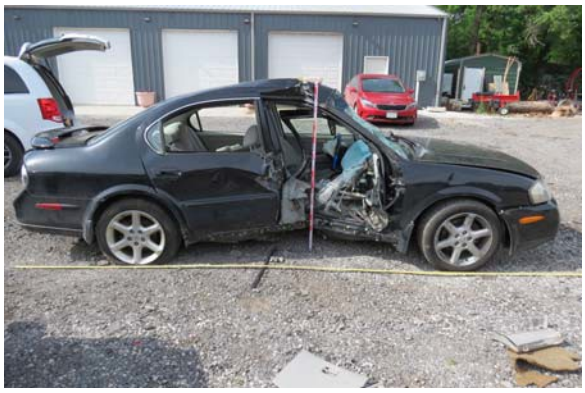


Figure 1. The 2003 Nissan Maxima

This crash occurred on the north roadside in the gore of a four-lane, divided, interstate highway interchange. A belted 19-year-old male drove the Nissan in a westerly direction in an unknown lane. The Nissan departed the right side of the roadway, and, as the driver steered left, the vehicle began to rotate counterclockwise. The right plane struck and fractured the break-away base of a luminaire (Event 1). The vehicle continued west and struck the SKT end terminal of a blocked-out W-beam guardrail (Event 2). The Nissan damaged 7.6 m (25.0 ft) of guardrail and four posts. The vehicle came to final rest, facing southeast, and engaged the end terminal that intruded into the front-row right position of the occupant compartment. The Nissan's driver, who sustained police reported "B" (non-incapacitating) injuries, was transported by ambulance to a hospital, where he was treated and released. The Nissan was towed from the crash site due to damage.

Summary

Crash Site

This crash occurred at night on the west roadside of a four-lane, divided, interstate highway. At the time of the crash, the National Weather Service reported the conditions as cloudy with southerly winds at 13 km/h (8 mph), a temperature of 23.3 °C (74 °F), and a dew point of 13.3 °C (56 °F). The police crash report listed the conditions as dark but lighted, clear, and dry. In the vicinity of the crash, the roadway curved to the right and was level. The interstate consisted of two bituminous through lanes in each direction, separated by a grass median with a cable guardrail median barrier. The travel lanes were 3.6 m (11.8 ft) wide. The westbound lanes were bordered by 0.6 m (2.0 ft) wide bituminous shoulder on the south and a 2.7 m (8.9 ft) wide bituminous shoulder on the north side. An exit lane that transitioned to an off-ramp was located north of the crash site. Roadway markings consisted of a solid yellow median edge line, a broken white center line, and a solid white west edge line. Rumble strips were cut into the north edge of the westbound travel lane. Several roads signs were located in the grass gore at the junction of the off-ramp and the north shoulder of the westbound travel lanes. A breakaway luminaire with a frangible base was located in the grass roadside 4.4 m (14.4 ft) prior to the guardrail end terminal. The W-beam guardrail system was located adjacent to the north shoulder of the westbound travel lanes that protected traffic from an embankment that transitioned to an intersection below. The end of the guardrail system was configured with an SKT end terminal. The posted speed limit was 105 km/h (65 mph). A crash diagram is included at the end of this report.

Pre-Crash

The Nissan was traveling in a southerly direction in the right travel lane at an unknown speed as the driver attempted to negotiate the right curve. He stated in the medical records and crash report that he dozed off. The vehicle drifted to the right and overrode the rumble strips (Figure 2). The driver apparently awoke and applied a rapid counterclockwise steering maneuver and braked in an attempt to regain the travel lane. This maneuver initiated a counterclockwise yaw evidenced by right front, right rear, and left front yaw marks on the south shoulder. The right-front tire yaw mark was 17 m (55.8 ft) in length prior to the first impact event. The yaw marks supported 50 degrees of counterclockwise rotation leading to the impact with the luminaire.

Figure 2. Southwest view of Nissan's roadway departure

Crash

The right plane of the Nissan, at the right-front door location, struck and fractured the breakaway base of a luminaire 18 cm (7.1 in) in diameter (Figure 3, Event 1). The force direction on the Nissan was in the 2 o'clock sector. The vehicle continued west for 4.4 m (14.4 ft) while continuing to rotate. The damaged right-front door area struck the end terminal of the W-beam guardrail system (Event 2). The force direction on the Nissan was in the 3 o'clock sector. The end terminal was displaced by the vehicle's center of mass and in line with the guardrail system. The SKT end terminal extruded 4.5 m (14.8 ft) of guardrail to the field side and damaged a total length of 7.6 m (25.0 ft) of guardrail as the Nissan remained engaged with the end terminal. Due to the lack of EDR data, it is unknown if the frontal air bags deployed during Event 1 or Event 2.

Figure 3. Southwest view, impact with luminaire

Post-Crash

The Nissan came to rest with its right plane fully engaged against the SKT end terminal (Figure 4). The driver unbuckled his seat belt, opened the left front door, and exited the vehicle unassisted. The police were notified of the crash and arrived on scene 7 minutes later. Rescue and medical personnel also responded. The driver sustained police-reported "B" (non-incapacitating) injuries and was transported by ambulance to a local hospital, where he was treated for his injuries and released. The Nissan was towed from the crash site to a local tow yard, where it was inspected for this investigation.

Figure 4. Northerly view, on-scene image of the Nissan at final rest

SKT End Terminal and Guardrail Damage

The right plane of the Nissan struck the end terminal and displaced the end terminal downstream. Approximately 4.5 m (14.8 ft) of guardrail was extruded toward the field side. The end terminal intruded into the vehicle and remained engaged with the vehicle at final rest. The impact face measured 51 cm (20.1 in) square and sustained minor damage (Figure 5). Post 1 became separated from its base. Post 2 collapsed downstream to the ground from its pivot base. Post 3 was collapsed downstream approximately 20 degrees, detached from the guardrail, and the composite offset block became partially detached from the post. Post 4 rotated slightly clockwise but remained attached to the composite offset block and guardrail. Posts 5 to 12 were not damaged and remained attached to the composite offset blocks and guardrail. The length of total damaged guardrail measured 7.6 m (24.9 ft) and there were no kinks downstream of the end terminal. Figure 6 is a view of the damaged guardrail section. The FHWA guardrail form is attached in Appendix A.

Figure 5. Southerly view, head of end terminal

Figure 6. Southerly view of damage to the guardrail system and displaced luminaire

2003 Nissan Maxima

Description

The Nissan Maxima was a four-door sedan with the SE trim package. It was manufactured in October 2002 and identified by Vehicle Identification Number JN1DA31D63Txxxxxx. The specified wheelbase was 275 cm (108.3 in). The Nissan was powered by a 3.5-liter, V-6 engine linked to a 4-speed automatic transmission with a console-mounted shift lever and front-wheel drive. The service brakes were power-assisted 4-wheel discs with ABS, electronic brake force distribution, and braking assist. The vehicle manufacturer's recommended tire size was P225/50R17. At the time of the crash, the Nissan was equipped with Firestone Firehawk AS tires on the front and Hankook Ventus S1 Noble2 on the rear wheels, all recommended size. The tires were all in good condition at the time of the crash and were mounted on 6-spoke OEM alloy wheels.

The interior of the Nissan was configured for seating of five occupants (2/3) with front-row bucket seats and a second-row bench seat with forward folding seat backs. All seating surfaces were cloth. The front row was equipped with adjustable head restraints while the second-row left and right positions were equipped with integrated head restraints. The top of the driver's head restraint was adjusted 25 cm (9.8 in) above the top of the seat back. Safety systems consisted of 3-point lap and shoulder belts for the five seat positions. The vehicle was also equipped with dual-stage, advanced frontal air bag inflators and front seat belt retractor pretensioners.

Exterior Damage, Event 1

The Nissan sustained damage to the right plane during the impact with the luminaire (Figure 7). The right front door, roof side rail, and sill were directly damaged. The direct-contact damage began 110 cm (43.3 in) rearward of the right front axle and extended 32 cm (12.6 in) rearward. Maximum crush was 39 cm (15.5 in) located on the sill 126 cm (49.6 in) rearward of the right

Figure 7. Right plane sill damage from luminaire impact

front axle. Crush measurements, documented at the sill level by total station, were as follows: C1 = 0 cm, C2 = 6 cm (2.4 in), C3 = 23 cm (9.1 in), C4 = 36 cm (14.2 in), C5 = 14 cm (5.5 in), and C6 = 3 cm (1.2 in). It should be noted that the sill crush was representative of the Event 1

damage, caused solely by the luminaire. WinSMASH could not be used to calculate delta V since impacts with yielding objects are out of scope for the program. However, WinSMASH was used to calculate a barrier equivalent speed of 22 km/h (13.7 mph) based on crush to the sill. The Collision Deformation Classification was 02RPAN3 (50 degrees).

Exterior Damage, Event 2

The right plane of the Nissan struck the SKT end terminal. The specific location involved the right front door, the B-pillar, and the leading edge of the right rear door, above the level of the sill. This impact damage overlapped the damage incurred to the right front door from the Event 1 luminaire impact (Figure 8). The direct damage began 74 cm (29.1 in) rear of the right front axle and extended 66 cm (26.0 in) rearward. Maximum crush was estimated at 60 cm (24.0 in) at the mid-level of the door due to separation of the components. The upper hinge of the right front door pulled through the sheet metal frame of the door. The lower hinge and door latch remained intact. The side impact door beam separated from its pocket mount at the aft aspect. Due to the overlapping damage at the door location, this crash event was outside the scope of the WinSMASH program. The Collision Deformation Classification was 03RPEW4 (80 degrees). The extent of the damage was estimated to be severe.

Figure 8. Right plane damage from the guardrail head impact (door sheet metal placed on by researcher)

Event Data Recorder

The Nissan was not equipped with an EDR supported by the Bosch Crash Data Retrieval tool.

Interior Damage

The interior of the Nissan sustained intrusion damage from the impacts with the luminaire and end terminal. The most severe intrusions involved the rear upper quadrant of the right front door and the right roof side rail, which intruded laterally 60 cm (23.6 in), 58 cm (22.8 in), and 50 cm (19.6 in), respectively. The lateral intrusion compressed the right aspect of the instrument panel inward. At maximum engagement, the intruding right front door panel contacted and tore the vinyl surface of the center mid-instrument panel. The right B-pillar displaced the right front seat back to the left and rearward. The lateral impacts and resultant damage to the right front door fractured and separated the interior door panel and the armrest. Inspection of the vehicle's interior revealed no discernable evidence of occupant contacts.

The right plane impacts fractured the laminated windshield and disintegrated the right front, right rear, and left rear door glazing. All door glazing was closed at the time of the crash.

Manual Restraints

The front row was equipped with 3-point lap and shoulder seat belts with sliding latch plates, adjustable D-rings, and retractor-mounted pretensioners. The driver's D-ring was adjusted to the full-down position. The second row was also equipped with three 3-point lap and shoulder seat belts with sliding latch plates.

Inspection of the driver's seat belt yielded evidence of historical usage. This included wear marks on the latch plate, edge fraying of the webbing, and the soiled condition of the webbing. There was no evidence of loading on the seat belt system; however, due to the lack of occupant contact and the lack of significant driver injury, it was determined that the driver was belted at the time of the crash. The PCR also listed the driver as belted.

Supplemental Restraints

The Nissan was equipped with dual-stage frontal air bags; both deployed during the crash.

The driver's frontal air bag in the steering wheel hub deployed through its tri-flap module cover. Each top flap was 8 cm (3.1 in) wide and 6 cm (2.4 in) high, and the bottom flap was 16 cm (6.3 in) wide and 11 cm (4.3 in) high. The cover flaps opened at the designated tear seams and were undamaged. The deflated air bag measured 59 cm (23.2 in) in diameter. No discernable contacts were noted on the air bag, but there were blood smears on the front lower center aspect and the upper left quadrant on the back of the air bag. Also, there was a small hole 2 mm (0.07 in) in the upper left quadrant of the front surface.

The passenger's frontal air bag was mounted in the top of the instrument panel and deployed through an H-configuration cover flap. The deflated air bag was 40 cm (15.7 in) wide and 48 cm (18.9 in) high. There were no discernable contacts noted, but there were several 3 cm (1.2 in) tears at the top right, bottom, and back of the air bag due to contact from the intruding right front door.

The Nissan was not equipped with side impact air bags.

NHTSA Recalls and Investigations

A VIN search of the NHTSA recall database did not yield any open recalls for this 2003 Nissan Maxima at the time of the crash.

2003 Nissan Maxima Occupant

Driver Demographics

Age/sex:	19-year-old/male
Height:	160 cm (63 in)
Weight:	68 kg (150 lb)
Eyewear:	Unknown
Seat type:	Bucket
Seat track position:	Between middle and rearmost positions
Manual restraint usage:	3-point lap and shoulder seat belt
Usage source:	Vehicle inspection
Air bags:	Driver's frontal available; deployed
Alcohol/drug data:	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	Laceration to right face	210602.1	Flying glass	Probable
2	Abrasions to right face	210202.1	Flying glass	Probable
3	Lacerations to right shoulder	710602.1	Flying glass	Probable
4	Contusion to right shoulder	710402.1	Intruding right front door panel	Probable
5	Lacerations to upper right arm	710602.1	Flying glass	Probable
6	Lacerations to lower right arm	710602.1	Flying glass	Probable
7	Lacerations to upper left arm	710602.1	Flying glass	Probable
8	Lacerations to lower left arm	710602.1	Flying glass	Probable
9	Abrasions to upper right arm	710202.1	Flying glass	Probable
10	Abrasions to lower right arm	710202.1	Flying glass	Probable
11	Abrasions to upper left arm	710202.1	Flying glass	Probable
12	Abrasions to lower left arm	710202.1	Flying glass	Probable

Source: emergency room records.

Driver Kinematics

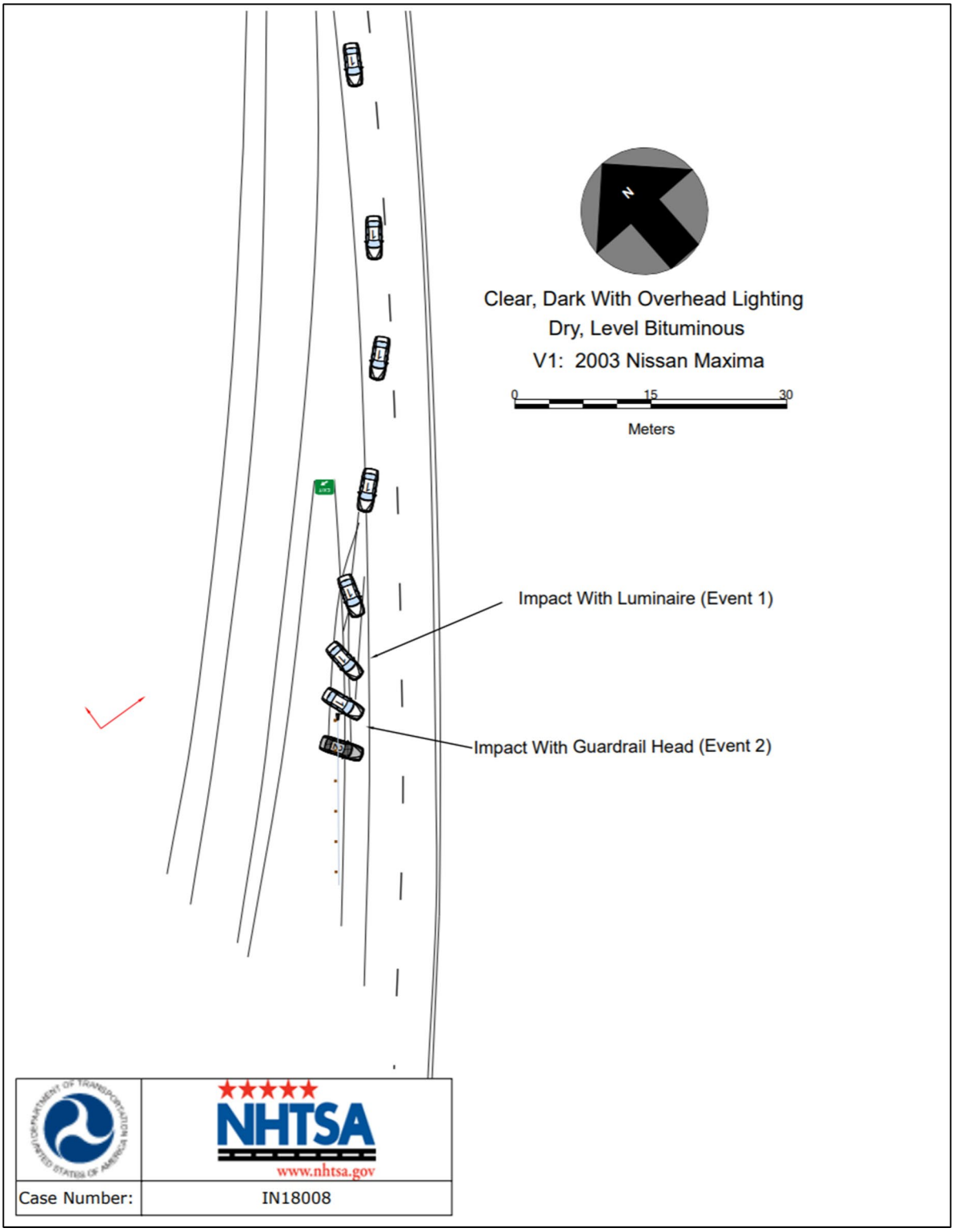
The driver was seated with the seat track adjusted between the middle and rearmost positions, and the head restraint was adjusted 25 cm (9.8 in) above the seatback. Based on the lack of occupant contact in the Nissan and the lack of significant injury, it was determined that the driver was belted at the time of the crash.

The right plane impact with the luminaire crushed the right front door and disintegrated the door glazing. The driver was displaced right and forward in response to the 2 o'clock direction of impact force. The lap belt held the driver's pelvic region in place as there was no contact to the console, the parking brake lever, or the transmission shifter. The driver's torso loaded the shoulder belt webbing, but due to the lateral impact force, his torso probably then slid out of the webbing. The disintegrated right-front door glazing sprayed across the interior of the Nissan and contacted the driver, resulting in lacerations and abrasions to the upper extremities.

The subsequent impact with the end terminal further displaced the driver to the right, and he probably contacted the intruded right front door panel, resulting in a contusion of the shoulder. There were no distinct contact points in the interior of the Nissan. Both frontal air bags deployed during the crash. Due to the lack of EDR data, the specific impact event for deployment could not be determined.

Immediately following the crash, the driver unbuckled his seat belt and exited the vehicle unassisted. He waited at the crash site for the arrival of the first responders. The driver was evaluated at the scene of the crash by EMS and transported by ambulance to a local hospital, where he was treated for his injuries and released.

Crash Diagram



Appendix A: FHWA Guardrail Form

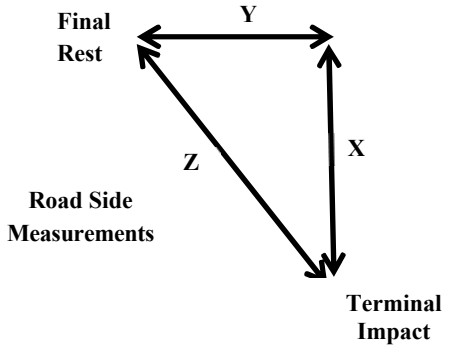
Case No.: IN18008

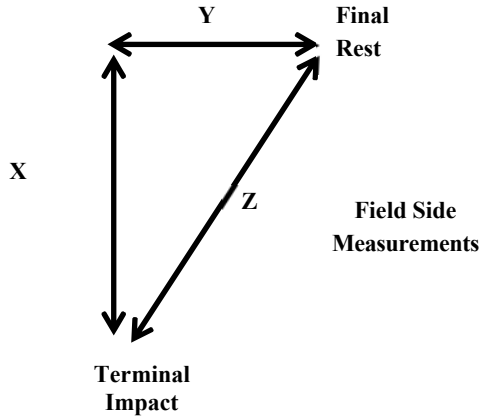
PREPOPULATED DATA (BY OTHERS)			
Date of Crash	May 2018	**TIME OF CRASH (MILITARY)**	Nighttime
Case Number	IN18008	**State**	MO
Traffic Route	I-35	**Direction (Southbound = SB)**	SB
Ambient Conditions (at time of crash)			
Temperature (°F)	74 °F	**Lighting**	Dark, With Overhead Light
Atmospheric			

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 = 13 ft
Est. distance (longitudinal) along guardrail from terminal impact to COM final resting location (ft.)	X = 13 ft
Est. distance (normal) from either 1. the white paint line; or 2. roadway/shoulder/pavement edge to COM rest position (ft.)	Y = 11 ft
Super elevation	❒+2% ❒-2% ☑ NONE or FLAT
Curve Radius (ft.)	592.1

KEY:

- COM - Center of Mass of Vehicle
- Distance Measurements





Case No.: IN18008

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	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1	Steel	6x6	N/A	N/A	Unknown	N/A	10.4		7’5”
2	Steel	6x4	N/A	N/A	Unknown	N/A	10.4		7’1”

Case No.: IN18008

GUARDRAIL INSTALLATION									
Post No.	Post		Offset Block		Pre-Existing Damage		Offset to Post or Post Hole (ft.)		Spacing to Next Post (ft. -in.)
	Type Steel Wood Other	Dim. D x W (in.) or Dia. (in.)	Type Steel Wood Composite	Dim. D x W (in.)	Yes No Unknown	Describe	Travel Way	Curb	
3	Steel	6x4	Comp	7.5x4	Unknown	N/A	10.5		6’1”
4	Steel	6x4	Comp	7.5x4	Unknown	N/A	10.6		6’
5	Steel	6x4	Comp	8x4	No	N/A	10.6		6’4”
6	Steel	6x4	Comp	8x4	No	N/A	10.4		6”1’
7	Steel	6x4	Comp	7.75x4	No	N/A	10.3		6’5”
8	Steel	6x4	Comp	7.75x4	No	N/A	10.3		6’2”

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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	5.5x4	Comp	7.75x4	No	N/A	10		3’2”
10	Steel	5.5x4	Comp	7.75x4	No	N/A	10.2		3’2”
11	Steel	6x4	Comp	8x4	No	N/A	10.2		2’11”
12	Steel	6x4	Comp	8x4	No	N/A	10’		3’4”

Additional Comments:

Case No.: IN18008

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.)	14’10”
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	❒Yes;	No. of Kinks in Rail:
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 - %	-17	-29	-30
Adjacent Lane Width (ft)	12’		
Lane Type (NAS EDS Variable: Sur. Type)	Bituminous		
Shoulder Type	Bituminous		
Shoulder Width (ft)	104”		
Guardrail Height (in)	30”		

Case No.: IN18008

VEHICLE INFORMATION		
Vehicle Type (NHTSA Input)	2003 Nissan Maxima	
Vehicle Identification Number (VIN)	JN1DA31D63Txxxxxx	
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	03RPEW4	
Delta-V	Unknown (overlapping damage)	
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
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**National Highway
Traffic Safety
Administration**

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