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Special Crash Investigations On-Site Guardrail End Terminal Crash Investigation Vehicle: 2001 Isuzu Trooper Location: Missouri Crash Date: July 2018

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16. Abstract <p>This single-vehicle crash occurred on a curved state road in Missouri. The Isuzu was traveling westbound and was being driven by a 34-year-old male. As the vehicle negotiated the curve, the driver lost control and the vehicle began a counterclockwise rotation as it departed the roadway to the north. The right side of the Isuzu struck the end terminal. The vehicle was redirected back onto the roadway and overturned. The driver was injured and transported from the scene and was hospitalized. The Isuzu was not supported by the Bosch Crash Data Retrieval (CDR) system.</p>			
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Table of Contents

BACKGROUND 1

SUMMARY 2

Crash Site..... 2

Pre-Crash 2

Crash..... 2

Post-Crash..... 3

GUARDRAIL END TERMINAL DISCUSSION 3

2001 ISUZU TROOPER 4

Description..... 4

Exterior Damage 4

Interior Damage 5

Manual Restraint Systems 5

Supplemental Restraint Systems 6

Rollover Mitigation..... 6

NHTSA Recalls and Investigations..... 6

2001 ISUZU TROOPER OCCUPANTS 6

Driver Demographics 6

Driver Injuries 7

Driver Kinematics 7

CRASH DIAGRAM 9

Appendix A: Federal Highway Administration Guardrail Data Forms A-1

Special Crash Investigations
On-Site Guardrail End Terminal Crash Investigation
Case Number DS18020
Vehicle: 2001 Isuzu Trooper
Location: Missouri
Crash Date: July 2018

BACKGROUND

This report documents the on-site guardrail end terminal investigation of the Trinity SoftStop guardrail end terminal struck by a 2001 Isuzu Trooper during a crash and the injuries sustained by the driver (**Figure 1**). The investigation is intended to determine what role the guardrail may have played in causing injuries to the driver. This case was initiated by the state transportation agency who notified the Federal Highway Administration (FHWA) of the crash. After reviewing the case and determining the guardrail end terminal qualified and the case was of interest, the FHWA forwarded the notification along with on-scene images to the Special Crash Investigations (SCI) group of the National Highway Traffic Safety Administration with instructions to deploy the SCI team. SCI assigned the case to Dynamic Science, Inc. in August 2018.



Figure 1. 2001 Isuzu Trooper

The crash scene and vehicle inspections were completed in August 2018, and state transportation agency employees were present for assistance and traffic control. The Isuzu was not supported by the Bosch Crash Data Retrieval system.

This single-vehicle crash occurred on a curved state road in Missouri. The Isuzu was traveling westbound and was being driven by a 34-year-old male. As the vehicle negotiated the curve, the driver lost control and the vehicle began a counterclockwise rotation as it departed the roadway to the north. The right side of the Isuzu struck the end terminal. The vehicle was redirected back onto the roadway and overturned. The driver was injured and transported from the scene and was hospitalized.

SUMMARY

Crash Site

The crash site was the westbound lane of a two-lane undivided state highway in a rural area of Missouri (**Figure 2**). The asphalt roadway was 7.6 m (25 ft) wide, curved to the left with a radius of 193.2 m (634 ft), had a positive two percent grade, and had a positive six percent superelevation. The travel lanes were unmarked but did have several reflector markers at irregular intervals. The roadway was bordered by unmarked aggregate/earth shoulders and W- beam guardrails with Trinity SoftStop end terminals. The roadway was dry and it was dark at the time of the crash. The posted speed limit was 89 km/h (55 mph). The weather at the nearest report station was 19 degrees C (66 degrees F), 90 percent humidity, clear visibility and the wind direction was southwest at 5 km/h (3 mph). A crash diagram is attached at the end of this technical report.

Pre-Crash

The Isuzu was traveling westbound in the first lane at an unknown speed while negotiating a left curve. For unknown reasons, the driver lost control of the vehicle and began a slight counterclockwise yaw. The vehicle partially departed the roadway approximately 15 m (49 ft) prior to the terminal end (**Figure 3**).

Crash

As the vehicle departed the shoulder on the right, the right plane struck the SoftStop end terminal treatment (**Figure 4**). The WinSMASH program calculated a barrier equivalent speed (BES) of 16 km/h (10 mph). The driver's and passenger's frontal air bags deployed during this impact. The results are borderline because the end terminal yielded and the damage to the vehicle was primarily longitudinal. As the guardrail engaged the side of the vehicle, including the B-pillar and right rear door, the vehicle began a clockwise rotation. Portions of the vehicle remained in contact to the guardrail face at posts 4-6.



Figure 2. Westbound approach



Figure 3. Westbound approach, right road edge departure



Figure 4. Guardrail end treatment impact

In the area between guardrail posts 10-12, approximately 18 m (60 ft) west of the terminal end, the vehicle struck the guardrail face with its front right bumper and possibly front right tire. The vehicle continued rotating clockwise before tripping and beginning a left side leading rollover. The vehicle continued rotating while rolling eight quarter turns before coming to rest on its wheels in an upright orientation facing south (**Figure 5**). The distance from the trip point to final rest was 47 m (154 ft).

Post-Crash

The driver was able to exit the vehicle under his own power. The driver sustained police-reported “A” (incapacitating) injuries. He was transported by ambulance to a local trauma center where he was admitted for his injuries. The vehicle was towed from the scene due to damage.

GUARDRAIL END TERMINAL DISCUSSION

The guardrail end terminal in this crash was a Trinity SoftStop tangent single-side redirective and gating terminal (**Figure 6**). It uses a moveable impact head on a W-beam rail section. During an end impact, the head travels down the anchored rails which are extruded toward the ground. The head measured 18 x 53 cm (7 x 21 in). Portions of the vehicle remained in contact to the guardrail face at posts 4 to 6. In the area between guardrail posts 10 to 12, approximately 18 m (60 ft) west of the terminal end, the vehicle struck the guardrail face with its front right bumper and possibly tire. The system was designed with an anchor post (post 0) and an anchor panel between post 0 and post 1. The head was located in front of post 1. The distance between post 0 and the terminal head was 129 cm (51 in). Posts 1 and 2 were steel and designed to yield. Composite offset block were installed on all posts except for posts 0 and 1. The guardrail height as measured in the field was 78 cm (30.7 in). During the crash, the SoftStop impact head was displaced west with 3.6 m (12 ft) extrusion toward the ground and came to a stop in front of post 3 (**Figure 7**). The total length of rail damaged was approximately 7.6 m (25 ft). This end terminal had been involved in a previous



Figure 5. Final rest, looking east (police provided photo)



Figure 6. Trinity SoftStop guardrail end terminal, looking north



Figure 7. Trinity SoftStop guardrail end terminal, looking west

crash. The terminal face label had been replaced at some time in the past. The old label had been marked with orange paint. The completed FHWA guardrail forms are included at the end of this report as **Appendix A**.

2001 ISUZU TROOPER

Description

The 2001 Isuzu Trooper was a five-door sport utility vehicle that was identified by the Vehicle Identification Number JACDJ58X117xxxxxx. The vehicle was configured with a 3.5-liter, 6-cylinder, gasoline engine, an automatic transmission, and 4-wheel drive. The vehicle manufacturer’s recommended tire size was P245/70R16 with a cold pressure of 207 kPa (30 psi) for the front and 241 kPa (35 psi) for the rear. The vehicle was equipped with P265/70R16 Hankook DynaPro tires. The specific tire information was as follows:

Position	Measured Pressure	Measured Tread Depth	Restricted	Damage
LF	Tire Flat	4 mm (5/32 in)	No	De-beaded
LR	Tire Flat	6 mm (8/32 in)	No	De-beaded
RR	Tire Flat	8 mm (10/32 in)	Yes	Sidewall torn
RF	Tire Flat	6 mm (7/32 in)	No	De-beaded

The Isuzu was configured with seating for five occupants. The front row was equipped with bucket seats with adjustable head restraints. Both front seats were adjusted to the rear most track position. The second row was configured with a bench seat with folding backs.

Exterior Damage

The Isuzu was involved in three damage producing events. The vehicle sustained moderate right plane damage from the impact with the end terminal (**Figures 8-9**). The damage began 1 cm (0.4 in) aft of front axle and extended 219 cm (86.2 in) rearward. The damage began 34 cm (13.3 in) above the ground at the right fender. The front right door was displaced from the vehicle. The second row right door and B-pillar were displaced rearward 38 cm (14.9 in). Twenty-four measurements were taken at the sill level by the Nikon Total Station and the Faro Blitz program computed crush measurement in six increments as follows: C1 = 13 cm (5.1 in), C2 = 12 cm (4.7in), C3 = 11 cm (4.3 in), C4 = 11 cm (4.3 in), C5 = 4 cm (1.5 in), C6 = 7 cm (2.7 in). The overall length of damage was adjusted to account for C



Figure 8. Right plane damage, 2001 Isuzu Trooper

values that were not accessible/visible for measurement. The Collision Deformation Classification (CDC) was 12RYEW2.

The vehicle appeared to contact the guardrail face with its front right bumper corner during rotation. The direct damage began at the front right bumper corner and extended 20 cm (7.8 in) to the left. The CDC was 10FRLE1.

The Isuzu sustained moderate top plane damage from the rollover (**Figure 10**). The direct damage measured 118 cm (46.4 in) roof side rail to roof side rail.

The maximum vertical crush was located 35 cm (13.7 in) right front left roof side rail on the windshield header and measured 31 cm (12.2 in). The CDC was 00TDDO4.

Interior Damage

The Isuzu sustained moderate interior damage from intrusion and occupant contacts (**Figure 11**). There was vertical intrusion of the roof, windshield header, and roof side rails. The front right door was displaced from the vehicle and the right rear door was deformed rearward, exposing the second row seats. The B-pillar was deformed 38 cm (14.9 in) rearward. The windshield glazing was fractured and the glazing was disintegrated at the front row left, front row right, second row right, and backlight. The left front, second row left, and rear doors remained closed and operational.

Manual Restraint Systems

The front row was equipped with driver and front right passenger lap and shoulder seat belts. The driver's belt was equipped with continuous loop belt webbing, a sliding latch plate, an emergency locking retractor (ELR), and an adjustable upper anchor that was adjusted to the full up position. The front right passenger's seat belt was equipped the same as the driver's, but had a switchable ELR/automatic locking retractor (ALR). The seat belts were not equipped with pretensioners. The driver's seat belt showed evidence of historical



Figure 9. Right plane damage, 2001 Isuzu Trooper



Figure 10. Rollover damage, 2001 Isuzu Trooper



Figure 11. Interior damage, 2001 Isuzu Trooper

usage and there were marks on the belt that came from the belt being used to secure the steering wheel during post-crash transport. There were no indications that the belt was used in this crash.

Supplemental Restraint Systems

The Isuzu's supplemental restraint systems included an air bag control module and driver's and passenger's redesigned frontal air bags. Both frontal air bags deployed during the initial guardrail end terminal impact. The driver's frontal air bag measured 60 cm (23.6 in) and had two vent ports. There was no indication of occupant contact on the air bag face. There were blood drops located on the back of the air bag. The passenger's frontal air bag measured 49 x 56 cm (19.2 x 22.0 in). It was undamaged and unremarkable.

Rollover Mitigation

This vehicle has not been rated by NHTSA. The control loss prior to the rollover was the result of impact forces associated with the impact to the guardrail end terminal. As the right plane of the Isuzu became fully engaged with end terminal, the vehicle began a clockwise rotation. After the vehicle had rotated approximately 100 degrees, the vehicle tripped on the road surface and began a left side leading rollover. The first ground contact was with the left D-pillar. The vehicle continued rotating and then began a roll with the right side leading. The vehicle continued rotating while rolling eight quarter turns before coming to rest on its wheels in an upright orientation facing south. The distance from the trip point to final rest was 47 m (154 ft).

NHTSA Recalls and Investigations

There were no open recalls for this vehicle. The database was last queried in June 2019.

2001 ISUZU TROOPER OCCUPANTS

Driver Demographics

Age/Sex:	34 years/male
Height:	Unknown
Weight:	Unknown
Eyewear:	Unknown
Seat type:	Bucket
Seat track position:	Rear most
Manual restraint usage:	Lap and shoulder seat belt not used
Usage source:	Vehicle inspection
Air bags:	Driver's frontal air bag deployed
Alcohol/Drug Data:	Positive for THC, 0.15 BAC
Egress from vehicle:	Under own power
Transport from scene:	Ambulance
Type of medical treatment:	Hospitalized, unknown number of days

Driver Injuries

Inj. No.	Injury	Injury Severity AIS 2015	Involved Physical Component (IPC)	IPC Confidence Level
1 2 3 4	T1, T2, T3, T10 superior end plate compression fractures with minimal height loss	650432.2	Seat cushion	Probable
5	Lung contusion, left	441406.2	ICS 1-Event 1 Left door (ICS confidence-Possible)	Probable
5	Lung contusion, left	441406.2	ICS 2- Event 3 Left door (ICS confidence-Probable)	Probable
6	Small left pneumothorax	442202.2	ICS 1-Event 1 Left door (ICS confidence-Possible)	Probable
6	Small left pneumothorax	442202.2	ICS 2- Event 3 Left door	Probable
7	Non displaced left rib fractures	450210.2	ICS 1-Event 1 Left door	Probable
7	Non displaced left rib fractures	450210.2	ICS 2- Event 3 Left door	Probable

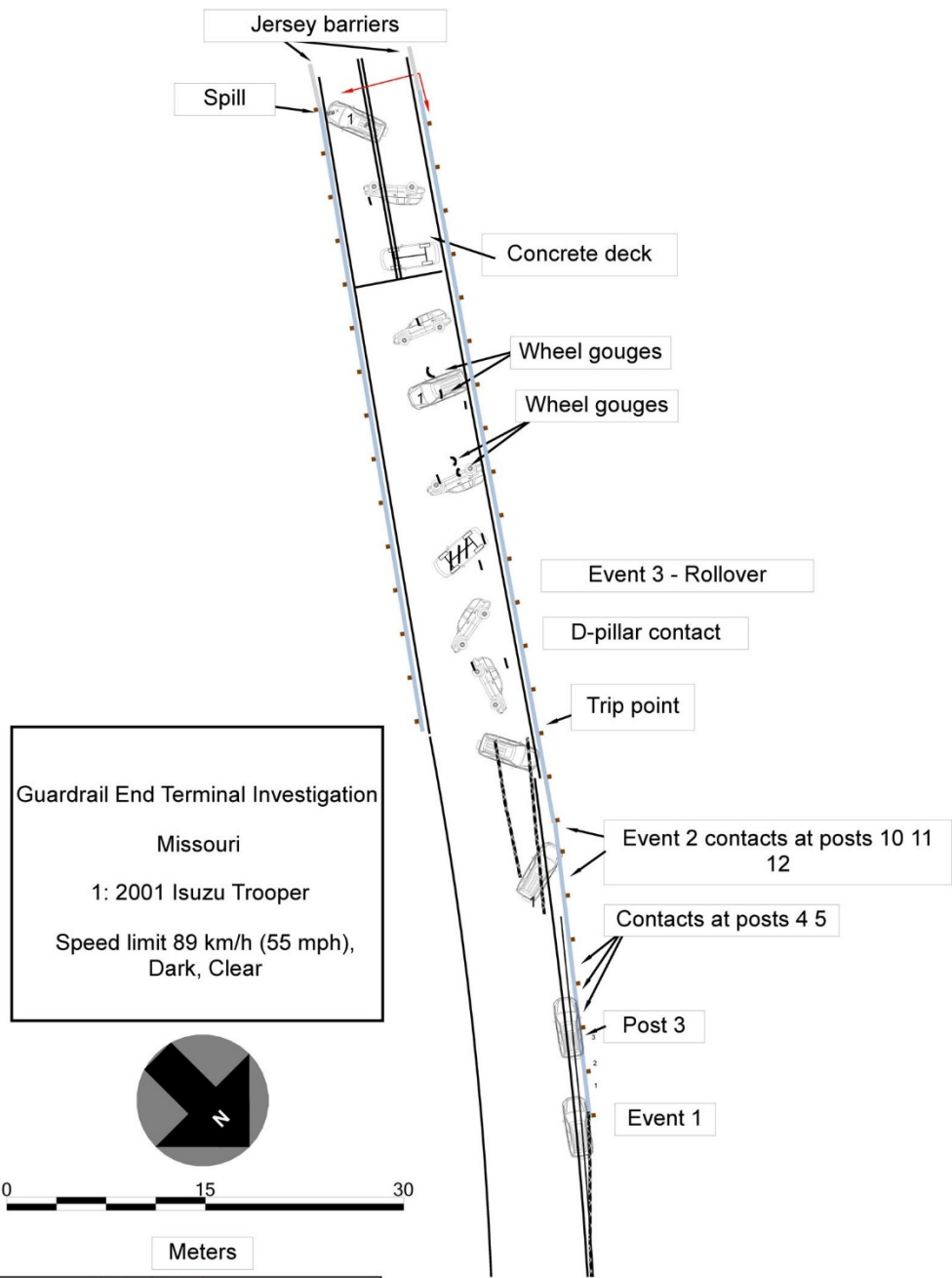
Source: Admittance record, physical exam, radiology report

Driver Kinematics

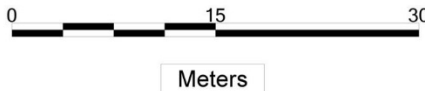
The 34-year-old male driver of the Isuzu was seated in an unknown posture with the seat track in the rear most position. The driver was not using the available seat belt. The vehicle was negotiating a left curve as it departed the roadway. At impact with the end terminal, the driver's frontal air bag deployed. The driver responded to the 12 o'clock direction of impact force by initiating a forward trajectory. His face and torso probably contacted the frontal air bag but there was no evidence of contact. During the engagement with the guardrail system, the Isuzu began a rapid clockwise rotation. The driver was displaced to the left and contacted the left door with his left torso. The vehicle tripped, rolled onto its left side, rotated and then began a right side leading rollover. The vehicle landed on its wheels during one rotation and then came to rest in an upright orientation. As the vehicle rolled, the driver was displaced in multiple directions but appeared to have remained in the front left seat position at final rest. The driver was able to exit the vehicle

without assistance. He was transported by ambulance to a local hospital where he was admitted and hospitalized for an unknown number of days.

CRASH DIAGRAM



Guardrail End Terminal Investigation
 Missouri
 1: 2001 Isuzu Trooper
 Speed limit 89 km/h (55 mph),
 Dark, Clear



	 www.nhtsa.gov
Case Number:	DS18020

**APPENDIX A: FEDERAL HIGHWAY ADMINISTRATION
GUARDRAIL DATA FORMS**

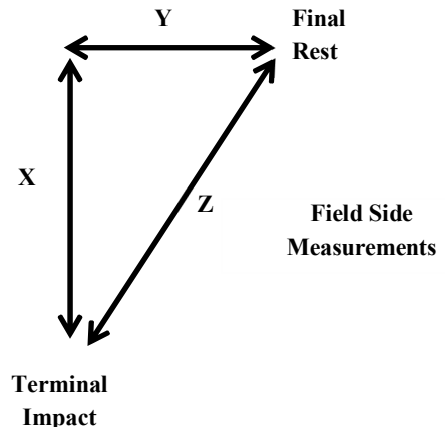
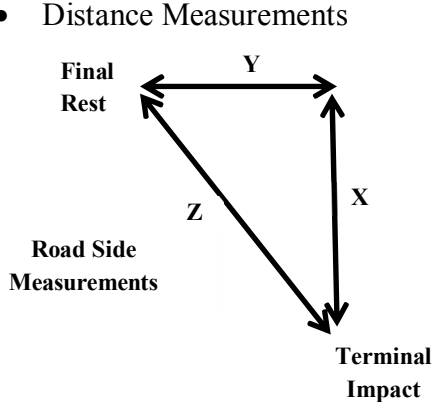
CASE NO.: DS18020

PREPOPULATED DATA (BY OTHERS)			
Date of Crash	July 2018	TIME OF CRASH (MILITARY)	Late night hours
Case Number	DS18020	State	MO
Traffic Route	Hwy B	Direction (Southbound = SB)	WB
Ambient Conditions (at time of crash)			
Temperature (°F)	66	Lighting	Dark
Atmospheric	Clear		

SCENE INFORMATION	
Type of area where crash occurred	<input type="checkbox"/> Urban <input checked="" type="checkbox"/> Rural <input type="checkbox"/> Suburban
Terminal on a horizontal curve?	<input type="checkbox"/> No <input checked="" type="checkbox"/> Curve/LT <input type="checkbox"/> Curve/RT
Estimated or Reconstructed Speed at Impact (mph)	➤ 54 mph
Est. distance (straight line) from terminal impact to COM final rest position (ft.)	Z = 257 ft
Est. distance (longitudinal) along guardrail from terminal impact to COM final resting location (ft.)	X = 254 ft
Est. distance (normal) from either 1. the white paint line; or 2. roadway/shoulder/pavement edge to COM rest position (ft.)	Y = 15 ft
Super elevation	<input checked="" type="checkbox"/> +2% <input type="checkbox"/> -2% <input type="checkbox"/> NONE or FLAT
Curve Radius (ft.)	634

KEY:

- COM - Center of Mass of Vehicle
- Distance Measurements



Case No.: DS18020

ON-SCENE INFORMATION	
End Treatment Type	<input checked="" type="checkbox"/> Extruder <input type="checkbox"/> ET2000 <input type="checkbox"/> ET-PLUS 4in <input type="checkbox"/> ET-PLUS 5in <input type="checkbox"/> SKT <input type="checkbox"/> FLEAT <input checked="" type="checkbox"/> SOFT STOP <input type="checkbox"/> Telescope <input type="checkbox"/> X-LITE <input type="checkbox"/> X-TENSION
Curb? s	<input checked="" type="checkbox"/> No <input type="checkbox"/> AASHTO Type A <input type="checkbox"/> AASHTO Type B <input type="checkbox"/> AASHTO Type C <input type="checkbox"/> AASHTO Type D <input type="checkbox"/> AASHTO Type E <input type="checkbox"/> Yes <input type="checkbox"/> AASHTO Type F <input type="checkbox"/> AASHTO Type G <input type="checkbox"/> 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	S	Unk	None	NA	No		2.5	NA		
1	S	6 x 4	None	NA	No		2.5	NA	4 ft 3 in	
2	S	4 x 6	C	4 x 8	No		3.5	NA	5 ft 5 in	

Case No.: DS18020

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	S	4 x 6	C	4 x 8	No		3.6	NA	6 ft
4	S	4 x 6	C	4 x 8	No		3.6	NA	6 ft 4 in
5	S	4 x 6	C	4 x 8	No		3.6	NA	6 ft 3 in
6	S	4 x 6	C	4 x 8	No		3.6	NA	6 ft 3 in

Case No.: DS18020

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.)						
7	S	4 x 6	C	4 x 8	No		3.6	NA	6 ft 2 in	
8	S	4 x 6	C	4 x 8	No		3.6	NA	6 ft 2 in	

Case No.: DS18020

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	S	4 x 6	C	4 x 8	No		3.6	NA	3 ft 1 in
10	S	4 x 6	C	4 x 8	No		3.3	NA	6 ft 3 in
11	S	4 x 6	C	4 x 8	No		3.4	NA	6 ft 3 in
12	S	4 x 6	C	4 x 8	No		3.6	NA	6 ft 3 in

Additional Comments

Case No.: DS18020

EXTRUDER			
Feeder Channel Width at impact head	<input type="checkbox"/> 4 inches	<input type="checkbox"/> 5 inches	<input checked="" type="checkbox"/> Other _____ 5.5 _____
Guide Chute Exit Height (in.)	13		
Connection of feeder channels to head damaged?	<input checked="" type="checkbox"/> No <input type="checkbox"/> Yes	Are Welds Broken?	<input checked="" type="checkbox"/> No <input type="checkbox"/> Yes
Anchor Cable Present?	<input type="checkbox"/> No <input checked="" type="checkbox"/> Yes	@ post 0	<input type="checkbox"/> No <input checked="" type="checkbox"/> Yes
Rail Extrusion?	<input type="checkbox"/> No <input checked="" type="checkbox"/> Yes	Length (ft. in.)	
Rail Extrusion Direction	<input type="checkbox"/> Traffic Side <input checked="" type="checkbox"/> Ground		
Total Length of Rail Damaged (ft.) [total length would include extruded rail plus damaged rail downstream from head.]	25		

TELESCOPE			
Rail Displacement	<input type="checkbox"/> No	<input type="checkbox"/> Yes; Length:	No of Panels Displaced <input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5 <input type="checkbox"/> 6

ALL-SYSTEM PERFORMANCE			
Railkinks Downstream of Head?	<input checked="" type="checkbox"/> No	<input type="checkbox"/> Yes;	No. of Kinks in Rail:
Was there intrusion into the Occupant Compartment by foreign object (guardrail)?	<input checked="" type="checkbox"/> No <input type="checkbox"/> Yes		
Did vehicle impact other objects after impact with terminal?	<input type="checkbox"/> No <input checked="" type="checkbox"/> Yes		
Object Contacted	Guardrail face, rollover		

ALL-SYSTEM PERFORMANCE ENVIRONMENT			
SIDESLOPE	50 ft in advance of Post 1	At Post 1	50 ft Past Post 1
Percent - %	10.7	12.0	5.2
Adjacent Lane Width (ft)	11		
Lane Type (NAS EDS Variable: Sur. Type)	Asphalt		
Shoulder Type	Aggregate/earth		
Shoulder Width (ft)	2.5 ft		

Case No.: DS18020

Guardrail Height (in)	31
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VEHICLE INFORMATION	
Vehicle Type (NHTSA Input)	2001 Isuzu Trooper SUV
Vehicle Identification Number (VIN)	JACDJ58X117XXXXXX
Vehicle Mass (NASS var.: veh.wgt)	2025 KG
Vehicle orientation upon impact	<input type="checkbox"/> Case Type 1 <input checked="" type="checkbox"/> Case Type 2 <input type="checkbox"/> Case Type 3 <input type="checkbox"/> Case Type 4 <input type="checkbox"/> Case Type 5 <input type="checkbox"/> Case Type 6 <input type="checkbox"/> Case Type 7 <input type="checkbox"/> Case Type 8 <input type="checkbox"/> Other
If 'Other', describe	NA
Collision Deformation Classification	12RYEW2
Delta-V	16 km (BES)
Occupant Compartment Penetration of rail	<input checked="" type="checkbox"/> No <input type="checkbox"/> Yes; Describe:
Quarter Turns (NASS EDS variable: Rollover)	<input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5 <input type="checkbox"/> 6 <input type="checkbox"/> 7 <input checked="" type="checkbox"/> 8 <input type="checkbox"/> 9 <input type="checkbox"/> 10 <input type="checkbox"/> 11 <input type="checkbox"/> 12 <input type="checkbox"/> 13 <input type="checkbox"/> 14 <input type="checkbox"/> 15 <input type="checkbox"/> 16 <input type="checkbox"/> 17+
Object Precipitating Rollover, (NASS EDS variable: Rollobj)	Ground
Rollover Type, Terhune Scale, (NASS EDS variable: rolintyp)	Around longitudinal axis

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September 2019



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