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ON-SITE ROLLOVER INVESTIGATION

CASE NUMBER - IN08019
LOCATION - MICHIGAN
VEHICLE - 2006 CHEVROLET C1500 SILVERADO
CRASH DATE - February 2008

Submitted:

February 9, 2009

Contract Number: DTNH22-07-C-00044

Prepared for:

U.S. Department of Transportation
National Highway Traffic Safety Administration
National Center for Statistics and Analysis
Washington, D.C. 20590-0003

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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 in order 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 vehicle(s) or their safety systems.

Technical Report Documentation Page

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15. *Supplementary Notes* On-site rollover investigation involving a 2006 Chevrolet C1500 Silverado extended cab pickup truck			
16. *Abstract* The focus of this report involves a 2006 Chevrolet that rolled over. This report covers an on-site investigation an oblique head-on crash that involved a 2006 Chevrolet C1500 Silverado that impacted a concrete median barrier with both its front and back planes before subsequently rolling over onto the road. The Chevrolet was traveling south on an icy interstate highway. The driver lost control of the vehicle due to road conditions and the Chevrolet began to rotate counterclockwise and traveled toward the median barrier. As the Chevrolet rotated off the barrier, it rolled over with its left side leading, two quarter turns onto its left side and top. The Chevrolet's driver (40-year-old, male) was seated and restrained by his lap-and-shoulder, safety belt system. The driver was transported later to a hospital by private conveyance and did not sustain any injuries as a result of this crash.			
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This crash was brought to the National Highway Traffic Safety Administration's attention on or before April 4, 2008 by the sampling activities of the National Automotive Sampling System–General Estimates System. This investigation was assigned on May 5, 2008. This crash involved a 2006 Chevrolet C1500 Silverado pickup truck that struck a concrete median barrier and rolled over. The crash occurred in February 2008, at 0655 hours, in Michigan and was investigated by the applicable township police. The focus of this investigation is because the Chevrolet rolled over. This contractor inspected the Chevrolet and imaged the Event Data Recorder (EDR) data on May 6, 2008. The scene was inspected and the driver interviewed on May 7, 2008. This report is based on the police crash report, scene and vehicle inspections, EDR data, an interview with the Chevrolet's driver, occupant kinematic principles, occupant medical records, and this contractor's evaluation of the evidence.

CRASH CIRCUMSTANCES

Figure 1: Chevrolet's southbound travel path in center lane of 7-lane, divided, trafficway

Crash Environment: The trafficway on which the Chevrolet was traveling was a 7-lane, divided interstate highway, traversing in a north-south direction. The southbound roadway had three through lanes while the northbound roadway had three through lanes and a lane leading to an exit ramp. The interstate highway was straight and level near the area of impact (**Figure 1**). The pavement was bituminous, but traveled, and the width of the travel lanes was 3.7 meters (12 feet). The shoulders were improved on both the east and west sides, and there was a concrete longitudinal barrier that divided the north and south roadways of the trafficway. Pavement markings for the roadway consisted of a solid yellow edge line on the west side and a solid white edge line on east side. In addition, the through lanes were divided by a dashed white lines. There were no visible traffic controls in the immediate area of the crash. The posted speed limit was 113 km/h (70 mph). At the time of the crash the light condition was dawn, the atmospheric condition was rain, and the roadway pavement was icy. Traffic density was light and the site of the crash was a urban commercial; see **CRASH DIAGRAM** on page 9 of this report.

Pre-Crash: The Chevrolet was traveling south in the center through lane and the driver intended to continue straight ahead. The Chevrolet's driver indicated that he lost control (i.e., skidded) on the icy roadway, began rotating counterclockwise, and moved toward the median. The driver applied the brakes and probably steered, attempting to avoid the crash. The Chevrolet's EDR data indicated that the vehicle was traveling 108 km/h (67 mph) 5 seconds prior to algorithm enable (AE) and the vehicle's brake switch circuit status was on. The driver continued braking prior to impact, and the pre-crash recording at 1 second prior to AE indicated that the brake switch circuit was on and the vehicle's speed at this time increment was recorded as 43 km/h (27 mph). The driver stated that hard, frozen snow was piled up against the median barrier in ramp-like fashion.

The crash occurred within an interchange area, in the median that separates the two roadways.

Figure 2: Damage to Chevrolet's front right corner from impact with median barrier

Figure 3: Damage to Chevrolet's back right corner from impact with median barrier

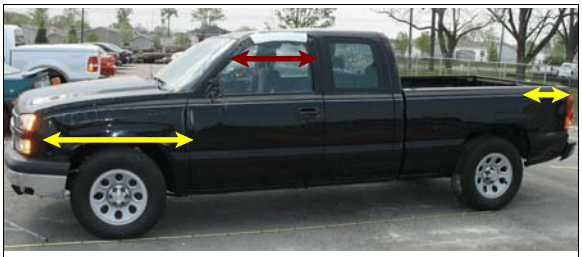


Figure 4: Arrows show areas of damage to the left side from the rollover

Figure 5: Overhead view of direct damage to Chevrolet's roof from the rollover and induced damage to windshield glazing

Crash: The front of the Chevrolet traveled up the frozen snow bank and the right portion of the vehicle's front bumper (**Figure 2**) impacted the median barrier (event 1). The vehicle rotated counterclockwise off the barrier and, as it rotated, the back traveled up the frozen snow bank. As a result, the vehicle was leaning to the left when its back right corner (**Figure 3**) impacted the median barrier (event 2). As the vehicle continued rotating counterclockwise off the barrier, it rolled over (event 3) with the left side leading. The vehicle rolled leftward two quarter turns (**Figure 4**), coming to rest on its top (**Figure 5**) in the inside southbound lane facing west-southwest. No air bags deployed during the crash sequence.

Post-Crash: The driver of the Chevrolet remained inside the vehicle at final rest. He was conscious and was able to exit the vehicle without any assistance through the driver's window. Police and emergency personnel were notified and responded to the crash scene. The driver called a friend, who arrived at the crash scene and transported the driver to a medical facility. Following the police investigation, the Chevrolet was towed due to damage.

CASE VEHICLE

The 2006 Chevrolet C1500 Silverado was a rear wheel drive, 6-passenger, 4-door, extended cab pickup truck (VIN: 1GCEC19ZX6Z------) equipped with a 5.3L, V-8 engine and a 4-speed

automatic transmission. This vehicle was manufactured during February 2006. Braking was achieved by a power-assisted, front disc and rear drum, 4-wheel, anti-lock system with electronic brake force distribution, multi stage driver and front right passenger air bag inflators, and driver and front right passenger seat belt buckle switch sensors. Furthermore, there was an occupant detection and automatic air bag suppression system for the front right passenger seating position. The air bag system in the vehicle is certified by the manufacturer to be compliant to the Advanced Air Bag portion of the Federal Motor Vehicle Safety Standard (FMVSS) No. 208. The Chevrolet was equipped Lower Anchors and Tethers for Children (LATCH) system features. The vehicle was also equipped with an Event Data Recorder (EDR). Inspection of the vehicle's interior revealed a 40/20/40 adjustable split bench seat with adjustable head restraints for the outboard seating positions and a non-adjustable second row, upward folding, bench seat with adjustable head restraints for the outboard seating positions.

The Chevrolet's wheelbase was 365 centimeters (143.7 inches), and the odometer reading at inspection 78,975 kilometers (49,073 miles).

Figure 7: Overhead view of Chevrolet's front crush profile with contour gauge placed at bumper level

CASE VEHICLE DAMAGE

Figure 6: Close-up view of damage to Chevrolet's front right bumper area

Exterior Damage: The Chevrolet's initial impact (event 1) with the median barrier involved the front bumper with the damage distributed on approximately the right portion (**Figure 6**). Direct damage began at the front right bumper corner and extended 46 centimeters (18.1 inches) along the front bumper. Residual maximum crush was measured as 7 centimeters (2.8 inches) at C_6 (**Figure 7**). The second impact (event 2) with the median barrier involved the vehicle's back bumper with the damage distributed on approximately the right portion. Direct damage began at the back right bumper corner and extended 6 centimeters

Figure 8: Damage to Chevrolet's back right bumper corner viewed from right

(2.4 inches) to the left (**Figure 8**). Crush measurements were taken on the back bumper and the residual maximum crush was 12 centimeters (4.7 inches) at C_6 (**Figure 9**). The table below shows the vehicle's crush profiles.

Figure 9: Overhead view of Chevrolet's back crush profile with contour gauge set a bumper level

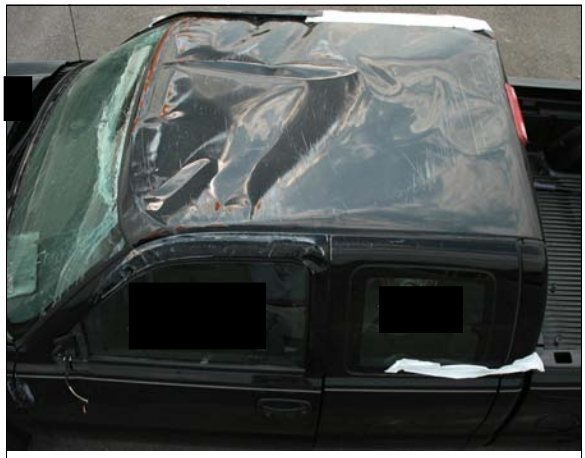


Figure 10: Overhead view from left of rollover damage to Chevrolet's extended cab and windshield; Note: damaged left outside rearview mirror

Units	Event	Direct Damage		Field L	C_1	C_2	C_3	C_4	C_5	C_6	Direct	Field L
		Width CDC	Max Crush								±D	±D
cm	1	46	7	173	1	1	1	2	6	7	64	0
in		18.1	2.8	68.1	0.4	0.4	0.4	0.8	2.4	2.8	25.2	0.0
cm	2	6	12	175	0	0	0	0	0	12	87	0
in		2.4	4.7	68.9	0.0	0.0	0.0	0.0	0.0	4.7	34.3	0.0

The rollover impact (event 3) involved the top and left side. Direct damage occurred to the left side and roof (**Figure 10**). The maximum lateral and vertical crush occurred at the right B-pillar (**Figure 5**). Based on the vehicle inspection and measurements from an exemplar vehicle, the maximum lateral crush was 6 centimeters (2.4 inches), and the maximum vertical crush was 9 centimeters (3.5 inches).

The wheelbase on the Chevrolet's left side was unaltered from the crash while the right side was extended 1 centimeter (0.4 inches). For the initial impact, the right portion of the front bumper and a small area of the right turn signal housing were directly damaged (**Figure 6**). The front bumper fascia was crushed rearward, restricting the movement of the right front wheel (**Figure 11**). For the second impact, the back right corner of the bumper fascia was directly damaged and crushed forward (**Figure 8**). During

Figure 11: Chevrolet's right front tire restricted by damaged front right bumper corner

the rollover, the direct damage on the left side consisted of scratches on the fender, front door, A-pillar, and roof side rail, and a dent in the left rear side of the truck bed (**Figure 4**). The left outside rearview mirror was also broken off the door (**Figure 10**). The direct damage on the top involved the full length and width of the roof (**Figures 5** and **10**). There was induced damage involving the front and back bumpers, the right side of the truck bed, and the windshield was cracked. When the vehicle was pulled onto its wheels during removal from the scene, the right outside rearview mirror was broken off the door, the right front door and fender were scratched, and the door was dented.

The vehicle manufacturer's recommended tire size was P245/70R17, but tire size P265/70R17 was optional; the Chevrolet was equipped with tire size P255/70R17. The vehicle's tire data are shown in the table below.

Tire	*Measured Pressure*		*Vehicle Manufacturer's Recommended Cold Tire Pressure*		*Tread Depth*		*Damage*	*Restricted*	*Deflated*
	kPa	psi	kPa	psi	milli-meters	32nd of an inch			
LF	262	38	241	35	10	12	None	No	No
LR	221	32	241	35	6	8	None	No	No
RR	234	34	241	35	6	8	None	No	No
RF	193	28	241	35	10	12	None	Yes	No

Vehicle Interior: Inspection of the Chevrolet's interior (**Figures 12** and **13**) revealed only occupant contact evidence on the roof above the driver's seat (**Figures 14** and **15**), consisting of a few hairs and a light scuff mark. The right B-Pillar intruded 7 centimeters (2.8 inches) laterally, and the roof intruded 6 centimeters (2.4 inches) vertically into the front right interior space. There was no evidence of steering rim deformation (**Figure 13**) or compression of the energy absorbing steering column.

Figure 12: Chevrolet's driver seating area showing no apparent contact evidence on steering wheel, instrument panel, or greenhouse areas and non-deployment of driver's air bag

Damage Classification: The Chevrolet's Collision Deformation Classifications for the Chevrolet were: **01-FREW-1** (**20** degrees) for the front impact with the median barrier (event 1), **05-BRLS-1** (**160** degrees) for the back impact with the median barrier (event 2), and **00-TPDO-2** for the rollover (event 3). The WinSMASH reconstruction program, Barrier algorithm, was used to reconstruct the Chevrolet's Delta Vs for the front

and back impacts. The Total, Longitudinal, and Lateral Delta Vs for the front impact were, respectively: 15.0 km/h (9.3 mph), -14.1 km/h (-8.8 mph), and -5.1 km/h (-3.2 mph). The EDR recorded a maximum longitudinal velocity change for this impact was -10.02 km/h (-6.23 mph). The Total, Longitudinal, and Lateral Delta Vs for the back impact were, respectively: 11 km/h (6.8 mph), 10.3 km/h (6.4 mph), and -3.8 km/h (-2.4 mph). The severity of the rollover damage was minor [2-13 km/h (1-8 mph)] based on the extent of crush to the top.

Figure 13: Chevrolet's driver seat area showing undeformed steering wheel rim and inside, windshield-mounted, rearview mirror broken off windshield by impact forces

Figure 14: Chevrolet's roof above driver seating area showing evidence (hair, scuff) of occupant contact

Figure 15: Frontal view of Chevrolet's roof above driver's seat with incremented tape showing area of hair and scuff mark on interior surface

AUTOMATIC RESTRAINT SYSTEM

The Chevrolet was equipped with driver and front right passenger CAC frontal air bags. The driver's air bag was located within the steering wheel hub. The front right passenger's air bag was located in the middle of the instrument panel. Neither air bag deployed in this crash.

MANUAL RESTRAINT SYSTEM

The Chevrolet's manual restraint systems are shown in the table below.

	Left	Center	Right
First Row	Continuous loop, integrated, lap-and-shoulder, safety belt system without upper anchorage adjustor or pretensioner; sliding type latch plate with ELR	lap belt with ELR	Continuous loop, integrated, lap-and-shoulder, safety belt system without upper anchorage adjustor or pretensioner; sliding type latch plate with switchable retractor type

	Left	Center	Right
Second Row	Continuous loop, lap-and-shoulder, safety belt system without upper anchorage adjustor for the D-ring; sliding type latch plate with switchable retractor type; lower anchor present; top tether anchor located behind the seat back	Continuous loop, lap-and-shoulder, safety belt system; sliding type latch plate with switchable retractor type; no lower anchor present; top tether anchor located behind the seat back	Continuous loop, lap-and-shoulder, safety belt system without upper anchorage adjustor for the D-ring; sliding type latch plate with switchable retractor type; lower anchor present; top tether anchor located behind the seat back
ELR = Emergency Locking Retractor		Switchable = either	ALR = Automatic Locking Retractor

Both front row outboard seat belts exhibited indications of historical usage. The inspection of the driver's safety belt webbing, shoulder belt guide, and latch plate revealed stretching due to loading as well as a pinch mark where the shoulder belt locked onto the integral belt guide (**Figures 16** and **17**).

Figure 16: Chevrolet's driver safety belt webbing showing loading evidence (oblique pinch mark and stretching) near should belt guide

Figure 17: Stretch marks on underneath side Chevrolet's driver safety belt near shoulder belt guide

CASE VEHICLE DRIVER KINEMATICS

The Chevrolet's driver applied the brakes and probably steered, attempting to avoid the crash. As a result of these attempted avoidance maneuvers, the vehicle's counterclockwise rotation, and the use of his available safety belts, the driver probably moved slightly forward and to his right just prior to impact. The Chevrolet's frontal impact with the median barrier (event 1) enabled the driver to continue forward and slightly rightward along a path opposite the vehicle's **20** degree direction of principal force as the vehicle decelerated. The Chevrolet's initial impact displaced the driver forward and to the right as he loaded his safety belts. Based on occupant kinematic principles, when the vehicle rebounded off the median barrier and during its subsequent continued counterclockwise rotation, the driver probably moved backward toward his seat back and to his left toward the driver's door. The Chevrolet's back impact with the median barrier (event 2) displaced the driver backward and slightly rightward where he loaded his seat back.

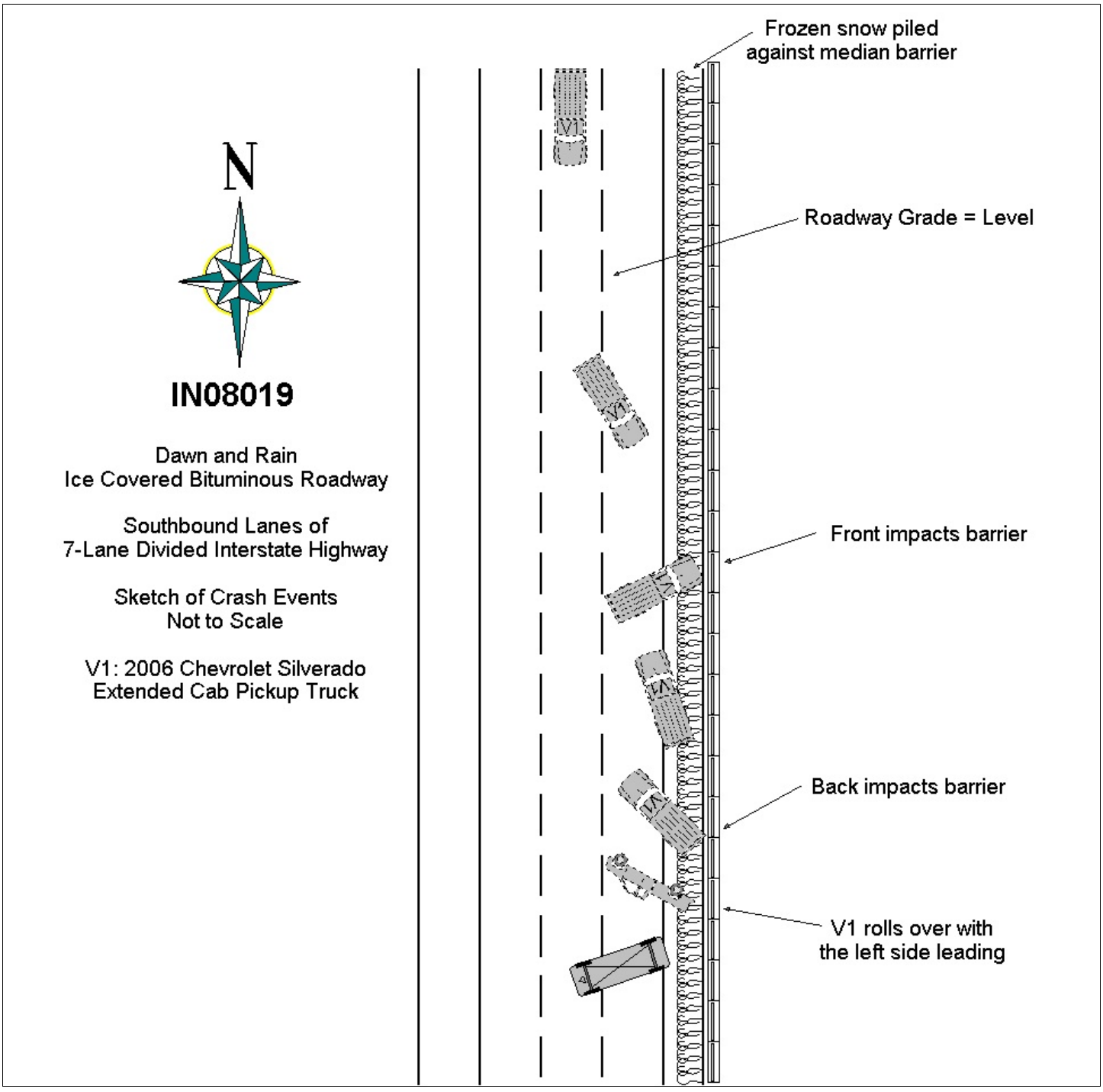
As the vehicle continued to rotate counterclockwise and roll over with the left side leading, the driver was displaced upward toward the roof and to the left.

Immediately prior to the crash, the Chevrolet's driver [40-year-old, male; 198 centimeters and 95 kilograms (78 inches and 210 pounds)] was seated in an upright posture with his back against the seat back, his left foot on the floor, his right foot on the brake, and both hands on the steering wheel at the 10 and 2 o'clock positions. His seat track was located in its rearmost position, the seat back was slightly reclined, and the location of steering column's tilt adjustment was full down. The driver stated he was wearing glasses at the time of the crash.

Based on this contractor's vehicle inspection and supported by the EDR data, the Chevrolet's driver was restrained by his safety belt system. The driver loaded his safety belts during the crash sequence but made no mention of belt pattern bruising and/or abrasions to his torso. Physical evidence indicates that the driver's head contacted the roof when the vehicle landed its top.

CASE VEHICLE DRIVER INJURIES

The driver of the Chevrolet was subsequently transported to a hospital by private conveyance. His employer insisted upon a "wellness check", and he was treated and released. The driver did not sustain any injuries as a result of this crash.


N
IN08019
Dawn and Rain
Ice Covered Bituminous Roadway
Southbound Lanes of
7-Lane Divided Interstate Highway
Sketch of Crash Events
Not to Scale
V1: 2006 Chevrolet Silverado
Extended Cab Pickup Truck
Frozen snow piled
against median barrier
Roadway Grade = Level
Front impacts barrier
Back impacts barrier
V1 rolls over with
the left side leading

CDR File Information

Vehicle Identification Number	1GCEC19ZX6Z******
Investigator	
Case Number	
Investigation Date	
Crash Date	
Filename	IN08019.CDR
Saved on	Tuesday, May 6 2008 at 02:47:26 PM
Collected with CDR version	Crash Data Retrieval Tool 2.900
Reported with CDR version	Crash Data Retrieval Tool 2.900
Event(s) recovered	Non-Deployment

SDM Data Limitations

SDM Recorded Crash Events:
There are two types of SDM recorded crash events. The first is the Non-Deployment Event. A Non-Deployment Event is an event severe enough to "wake up" the sensing algorithm but not severe enough to deploy the air bag(s). It contains Pre-Crash and Crash data. The SDM can store up to one Non-Deployment Event. This event can be overwritten by an event that has a greater SDM recorded vehicle forward velocity change. This event will be cleared by the SDM after the ignition has been cycled 250 times.
The second type of SDM recorded crash event is the Deployment Event. It also contains Pre-Crash and Crash data. The SDM can store up to two different Deployment Events, if they occur within 25.4 seconds of one another. Deployment Events cannot be overwritten or cleared from the SDM. Once the SDM has deployed the air bag, the SDM must be replaced.
The data in the Non-Deployment Event file will be locked after a Deployment Event, if the Non-Deployment Event occurred within 5 seconds before the Deployment Event. If multiple Non-Deployment Events occur within 5 seconds prior to a Deployment Event, then the most severe Non-Deployment Event will be recorded and locked. If multiple Non-Deployment Events precede a Deployment Event, and multiple Non-Deployment Events occur within 5 seconds of each other (but not necessarily all within 5 seconds of the Deployment Event), and subsequent Non-Deployment Events are less severe than prior Non-Deployment Events, and the last of the multiple Non-Deployment Events occurs within 5 seconds of a Deployment Event, then the most severe of the Non-Deployment Events (which may have occurred more than 5 seconds prior to the Deployment Event) will be recorded and locked.

SDM Data Limitations:
-SDM Recorded Vehicle Forward Velocity Change reflects the change in forward velocity that the sensing system experienced during the recorded portion of the event. SDM Recorded Vehicle Forward Velocity Change is the change in velocity during the recording time and is not the speed the vehicle was traveling before the event, and is also not the Barrier Equivalent Velocity. This data should be examined in conjunction with other available physical evidence from the vehicle and scene when assessing occupant or vehicle forward velocity change. For Deployment Events and Deployment Level Events, the SDM will record 100 milliseconds of data after deployment criteria is met and up to 50 milliseconds before deployment criteria is met. For Non-Deployment Events, the SDM will record the first 150 milliseconds of data after algorithm enable.
-Event Recording Complete will indicate if data from the recorded event has been fully written to the SDM memory or if it has been interrupted and not fully written.
-SDM Recorded Vehicle Speed accuracy can be affected if the vehicle has had the tire size or the final drive axle ratio changed from the factory build specifications.
-Brake Switch Circuit Status indicates the status of the brake switch circuit.
-Pre-Crash Electronic Data Validity Check Status indicates "Data Invalid" if the SDM receive an invalid message from the module sending the pre-crash data.
-Driver's and Passenger's Belt Switch Circuit Status indicates the status of the seat belt switch circuit. If the vehicle's electrical system is compromised during a crash, the state of the Belt Switch Circuit may be reported other than the actual state.
-The Time Between Non-Deployment and Deployment Events is displayed in seconds. If the time between the two events is greater than 25.4 seconds, "N/A" is displayed in place of the time.
-If power to the SDM is lost during a crash event, all or part of the crash record may not be recorded.
-Multiple Events Associated with this Record: This parameter will indicate whether one or more associated events preceded the recorded event.
-One or More Associated Events Not Recorded: If a single event is recorded, this parameter will indicate whether one or more associated events, prior to the recorded event, was not recorded.
If two associated events are recorded, this parameter for the first event will indicate whether one or more associated events, prior to the first event, was not recorded.
If two associated events are recorded, this parameter, for the second event, will indicate whether one or more associated events, between the first and second events, was not recorded.

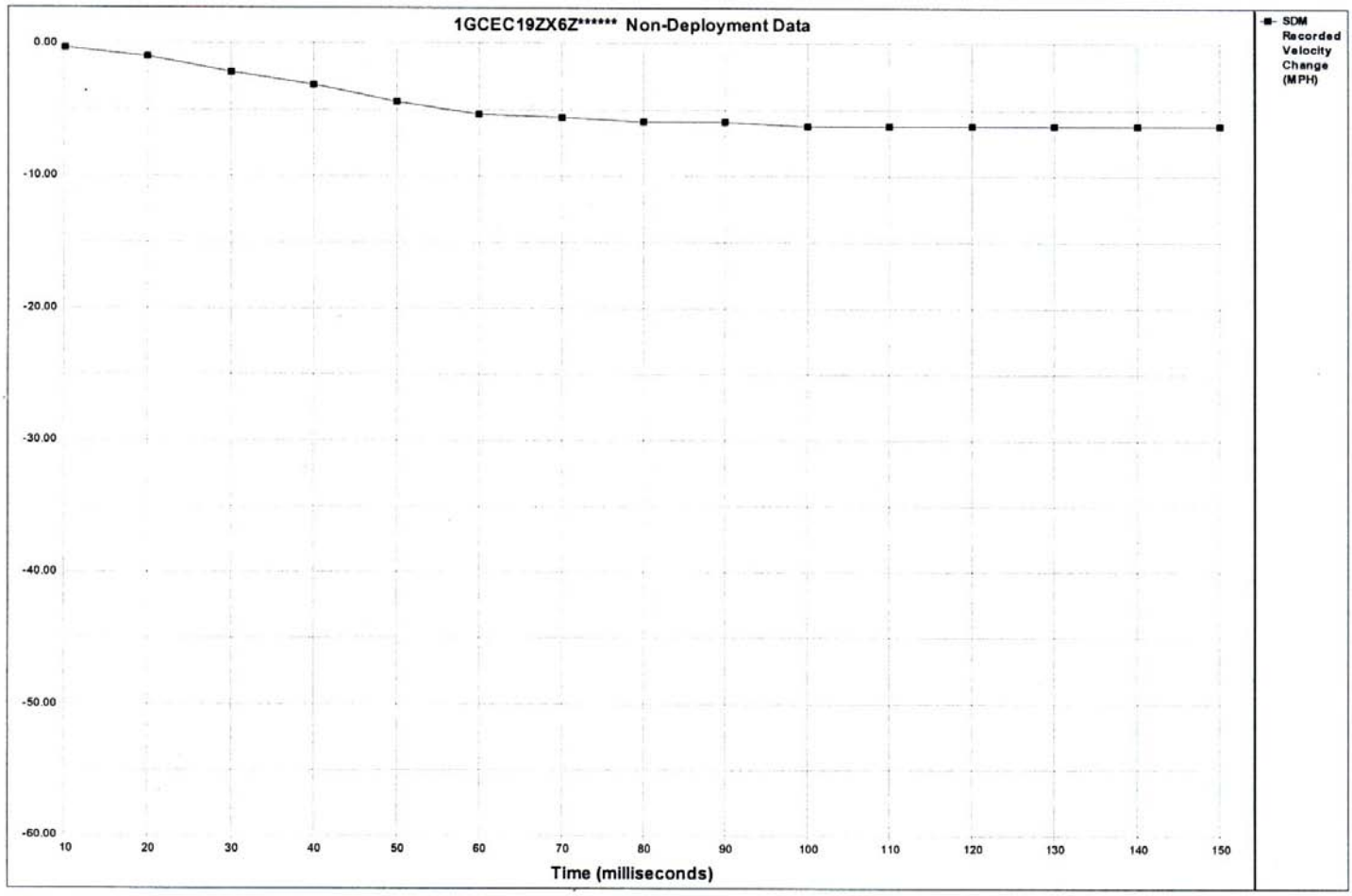
SDM Data Source:
All SDM recorded data is measured, calculated, and stored internally, except for the following:
-Vehicle Speed, Engine Speed, and Percent Throttle data are transmitted once a second by the Powertrain Control Module (PCM), via the vehicle's communication network, to the SDM.
-Brake Switch Circuit Status data is transmitted once a second by either the ABS module or the PCM, via the vehicle's communication network, to the SDM.
-The SDM may obtain Belt Switch Circuit Status data a number of different ways, depending on the vehicle architecture. Some switches are wired directly to the SDM, while others may obtain the data from various vehicle control modules, via the vehicle's communication network.

System Status At Non-Deployment

SIR Warning Lamp Status	OFF
Driver's Belt Switch Circuit Status	BUCKLED
Passenger's Belt Switch Circuit Status	UNBUCKLED
Passenger Seat Position Switch Circuit Status	Rearward
Ignition Cycles At Non-Deployment	9040
Ignition Cycles At Investigation	9051
Maximum SDM Recorded Velocity Change (MPH)	-6.23
Algorithm Enable to Maximum SDM Recorded Velocity Change (msec)	92.5
Crash Record Locked	No
Event Recording Complete	Yes
Multiple Events Associated With This Record	No
One Or More Associated Events Not Recorded	No

Seconds Before AE	Vehicle Speed (MPH)	Engine Speed (RPM)	Percent Throttle
-5	67	1600	0
-4	50	1280	0
-3	48	1152	0
-2	39	896	0
-1	27	640	0

Seconds Before AE	Brake Switch Circuit Status
-8	OFF
-7	OFF
-6	OFF
-5	ON
-4	ON
-3	ON
-2	ON
-1	ON



Time (milliseconds)	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150
Recorded Velocity Change (MPH)	-0.31	-0.93	-2.17	-3.10	-4.34	-5.27	-5.58	-5.89	-5.89	-6.20	-6.20	-6.20	-6.20	-6.20	-6.20