TRANSPORTATION SCIENCES
CRASH DATA RESEARCH CENTER

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REDESIGNED AIR BAR SPECIAL STUDY
NASS/SCI COMBINED DRIVER FATALITY INVESTIGATION

VERIDIAN CASE NO. 2000-49-254A

VEHICLE - 2000 DODGE RAM 3500 PICKUP TRUCK

LOCATION - TEXAS

CRASH DATE - NOVEMBER 2000

Contract No. DTNH22-94-07058

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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 of the involved vehicle(s) or their safety systems.

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17. *Abstract*

This remote investigation focused on the fatal injury mechanisms of a 41 year old male driver of a 2000 Dodge Ram 3500 Pickup Truck and the performance of the vehicle's occupant protection. The Dodge was equipped with integrated lap and shoulder belts for the front outboard seat positions and a front Supplemental Restraint System consisting of redesigned driver and front right passenger air bags. The driver was restrained by the integrated belt system and the frontal air bags deployed as a result of an underride crash with the back plane of a tractor/semi-trailer. During the impact sequence, the driver loaded the integrated belt system causing the seat back to flex forward. This allowed the driver greater forward excursion and resulted in contact with the intruding windshield and windshield header. The driver's contact with the intruding components resulted in fatal injuries.

The crash was identified and subsequently selected for investigation by PSU 49 of the National Automotive Sampling System (NASS). The Crash Investigations Division of the National Highway Traffic Safety Administration (NHTSA) was informed of the crash by Zone Center 2 on January 24, 2001 and the potential defect of the seat anchors in the Dodge. The NASS investigation revealed the left front seat anchor separated from the floor pan as a result of the crash. The NASS investigation concluded that the anchor separation may have been a causal factor in the driver's fatal outcome.

The potential of the defect caused NHTSA to assign a remote level investigation of the crash to the Special Crash Investigations Team at Veridian Engineering. The research data collected by the NASS level investigation was analyzed and it was determined the anchor separation occurred as a result of the floor pan deformation, late in the impact sequence. The seat anchors were not defective and were not a causal factor leading to the fatal injury. The SCI investigation determined the driver's fatal injuries resulted from the reduced effectiveness of the vehicle's integrated restraint system, that occurs in a high severity impact, coupled with the severe occupant compartment intrusion.

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BACKGROUND

This remote investigation focused on the fatal injury mechanisms of a 41 year old male driver of a 2000 Dodge Ram 3500 Pickup Truck and the performance of the vehicle's occupant protection. The Dodge was equipped with integrated lap and shoulder belts for the front outboard seat positions and a front Supplemental Restraint System consisting of redesigned driver and front right passenger air bags. The driver was restrained by the integrated belt system and the frontal air bags deployed as a result of an underride crash with the back plane of a tractor/semi-trailer. During the impact sequence, the driver loaded the integrated belt system causing the seat back to flex forward. This allowed the driver greater forward excursion and resulted in contact with the intruding windshield and windshield header. The driver's contact with the intruding components resulted in fatal injuries.

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SUMMARY

Crash Site

This two-vehicle crash occurred during the morning hours of November, 2000. At the time of the crash, it was dark with overhead street lighting and the weather was not a factor. The asphalt road surface was dry. The crash occurred in center lane of a five-lane divided Interstate highway within the city limits. The road was straight, with a positive grade (<2 percent) in the direction of travel, in the area of the crash. The

speed limit in the area was 89 km/h (55 mph). **Figure 1** is an eastbound trajectory view near the area of impact.

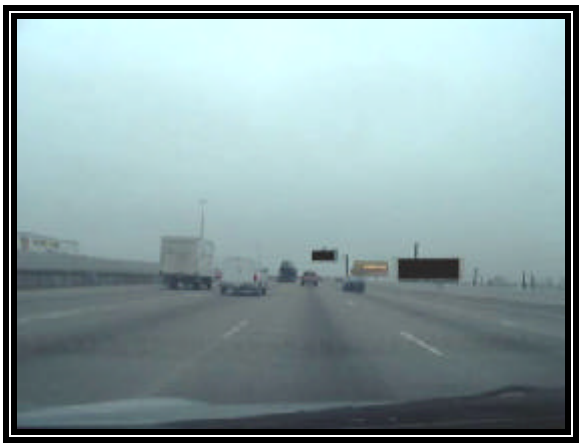

Figure 1: Eastbound trajectory view near the area of impact.

Pre-Crash

A 1998 Freightliner tractor/semi-trailer was eastbound in the center lane of the highway. The tractor driver estimated his speed was 80 km/h (50 mph). The 2000 Dodge Ram was driven by a 41 year old restrained male with a reported height and weight of 193 cm (76 in) and 106 kg (234 lb). The Dodge was eastbound in the center lane, traveling behind and approaching the tractor/semi-trailer. An analysis of the crash, based on the concepts of energy and momentum conservation, determined the pre-crash speed of the Dodge was approximately 121 to 129 km/h (75 to 80 mph). The driver of the Dodge failed to recognize the slower traffic in front of him and took no avoidance maneuvers prior to impact. No pre-impact skid marks from the Dodge Pickup were identified.

Crash

The crash occurred when the front of the Dodge impacted and underrode the back plane of the semi- trailer in a 12/6 o'clock impact configuration. The Dodge sustained a delta V of approximately 37 to 45 km/h (23 to 28 mph). The force of the collision caused the deployment of the vehicle's frontal air bag system. The underride damage and intrusion into driver's occupant space was severe. The vehicle came to rest within the eastbound travel lanes, however, its final rest position was not documented. The tractor driver reportedly felt the collision and brought his vehicle to a controlled stop on the roadside approximately 107 m (350 ft) east of the area of impact. The delta V of the tractor/semi-trailer was approximately 1.6 to 3.2 km/h (1 to 2 mph).

Post-Crash

The driver of the Dodge was fatally injured in the crash and was pronounced dead at the scene by the medical examiner. He was trapped in the vehicle due to the intrusion and had to be extricated. He was subsequently transported to the Medical Examiner's office and an autopsy was conducted. The driver's blood alcohol content (BAC) was determined to be 0.19. The semi-trailer sustained, police reported, minor damage and was placed back-in-service. The tractor driver drove the vehicle from the scene at the conclusion of the police investigation. The tractor/semi-trailer was not available for inspection.

2000 DODGE RAM 3500 PICKUP TRUCK

The 2000 Dodge Ram was identified by the Vehicle Identification Number (VIN): 1B7MC33W3Y (production sequence deleted).. The 2-wheel drive, 1-ton, pickup truck was designed as a Quad-Cab, 4-door model, with a 393 cm (154.7 in) wheelbase. The cargo bed was 2.4 m (8.0 ft) in length. The

vehicle had a gross vehicle weight rating of 4,990 kg (11,000 lb). The power-train consisted of an 8.0 liter/V-10 engine linked to a 4-speed automatic transmission. The service brakes were a front disc/rear drum hydraulic system with a 4-wheel anti-lock system (ABS). The Supplemental Restraint System consisted of redesigned driver and front right passenger air bags that had deployed as a result of the above threshold crash. The electronic odometer could not be read at the time of the NASS inspection.

Exterior Damage

Figures 2 and 3 are the left front and left side views of the Dodge Ram, respectively. As a result of the crash, the Dodge sustained moderate damage at the bumper elevation and severe above bumper damage, as a result of the underride. The width of the direct contact damage extended across the full frontal width of the vehicle. Crush measurements were taken along the bumper elevation and the upper radiator support. The average profile of the crush measurements was as follows: C1=56.0 cm (22.0 in), C2=49.0 cm (19.3 in), C3=46.0 cm (18.1 in), C4=43 cm (16.9 in), C5=36 cm (14.2 in), C6=36 cm (14.2 in). The maximum crush at the bumper elevation was located at C1 and measured 28.0 cm (11.0 in). The maximum above bumper crush was 84.0 cm (33.1 in) at the C1 location. The energy of the crash was managed primarily by the vehicle's component above the level of the bumper. There was no measurable change in either wheelbase dimension.

Figure 2: Left front view of the Dodge.

Figure 3: Left side view.

The longitudinal extent of the direct contact, as a result of the underride of the inverted step profile of the box trailer, measured approximately 180 cm (71 in). This measurement was taken from the front plane and terminated at the front aspect of the roof . The hood and upper fenders buckled and deformed rearward into the A-pillars and cowl. The windshield and windshield header impacted the eack plane box trailer. The post-impact rake angle of the A-pillar was approximately 10 degrees. The Collision Deformation Classification (CDC) of the Dodge was 12-FDAA-7.

The dynamics of this crash were beyond the scope of the WINSMASH model. However, in order to estimate an upper limit of the crash severity, the Barrier Algorithm was used. The WINSMASH model calculated a barrier equivalent delta V of 43.9 km/h (27.3 mph), using the average crush profile . It should be noted that the Barrier Algorithm assumes no energy is absorbed by the barrier and the barrier does not move. Clearly in the crash, the trailer was not a fixed barrier and it was damaged (absorbed energy) in the crash, therefore the above calculation represents an upper limit. A crash analysis based on the principles of conservation of energy and momentum determined the delta V of the Dodge was 37 to 45 km/h (23 to 28 mph). There was reasonable agreement between the two methods of analysis.

Interior Damage

The interior of the Dodge sustained severe damage and intrusion as a result of the exterior forces of the crash. **Figure 4** is a left view of the driver's interior taken during the NASS inspection. The measured intrusion of the windshield header and base of the windshield, along the vehicle's centerline, was 23 cm (9 in) and 57 cm (22 in) respectively. The longitudinal intrusion of the left side of the instrument panel measured 44 cm (17 in). There was 18 cm (7 in) of intrusion at the driver's toe pan. Contact scuffs to the knee bolster and left lower outboard aspect of the instrument panel from the driver's left lower extremity were documented. The driver was trapped by the intruded components and required extrication. A temporary wedge holding up the instrument panel is visible in the lower aspect of Figure 4.

Figure 4: Left interior view.

Figures 5 and 6 are views of the 4-spoke steering wheel rim. The tilt mechanism of the steering wheel was adjusted between full up and center, based on the NASS investigation and appeared to be fractured. The plane of the steering wheel rim was loaded by the driver's abdomen during the crash and deformed. The upper aspect of the column was in a near vertical position. The upper aspect of the steering wheel rim contacted and fractured the horizontal surface of the instrument panel. Shear capsule displacement was not recorded.

Figure 5: Left lateral view of the steering wheel rim.

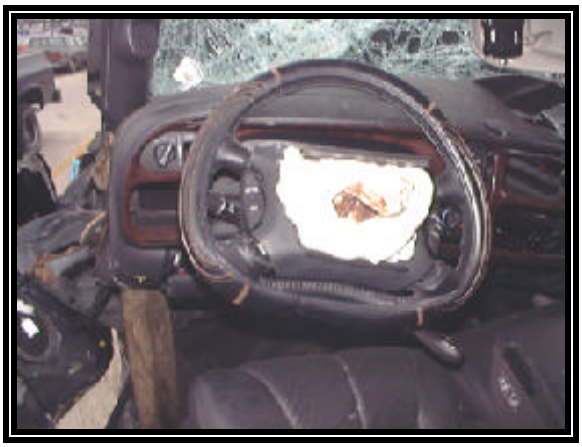

Figure 6: Forward view of the steering wheel rim.

Figure 7 is a view of the separated left front seat anchor that initiated the Potential Safety Problem Bulletin from the NASS Zone Center. The hold down fastener appeared to have pulled through the floor during the crash sequence. This type of failure occurs by the application of a tensile force to the seat and fastener, reacted by the floorpan. During the crash sequence, the front seat anchors are placed in compression by the forward kinematic sequence of the driver. The rear seat anchors are placed in tension. If failure would have occurred as a result of the driver's inertial loading, that failure would have first occurred at the rear anchors. Referring to Figure 7, the buckling of the floorpan is very evident in the area of the fastener. The failure of the anchor probably occurred as a result of the localized buckling in the area of the fastener widening the clearance hole in the floorpan sufficiently to cause the separation. This failure would have occurred late in the crash sequence and had no bearing on the driver's kinematics.

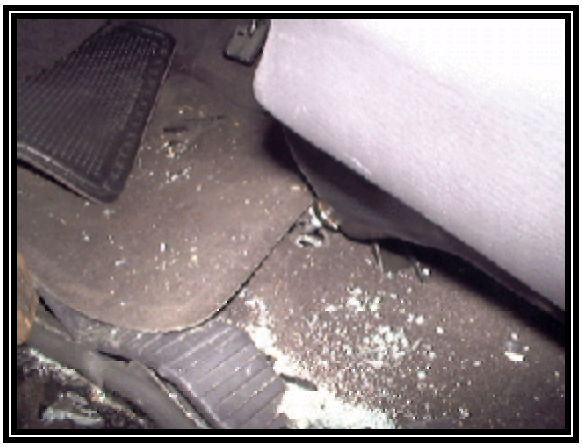

Figure 7: Buckled floor pan and left front seat anchor.

Integrated Restraint System

The manual 3-point lap and shoulder restraint in the front outboard positions of the 2000 Dodge Ram was an integrated seat belt system. The inertial retractor and belt path were integrated into the outboard aspects of the seat backs. The lap portion of the webbing was anchored to the outboard aspect of the seat track. The inboard buckle anchor was attached to the inboard aspect of the track. In this manner, the manual restraint can give the occupant a consistent fit, regardless of seat track position. The integration of the retractor from the upper B-pillar into the seat back allowed for the addition of the second door on the Quad Cab model.

Upon inspection, the sliding latch plate was inserted and latched to the buckle anchor. The webbing had been cut by the EMS personnel during extrication. The lap/shoulder portion of the cut section was on the seat. The balance of the shoulder webbing had spooled back into the retractor and could not be accessed. Blood stains were noted on the shoulder portion of the webbing. These evidences were consistent with proper belt use in this crash.

Supplemental Restraint System

The Supplemental Restraint System in the Dodge Ram consisted of redesigned driver and front right passenger air bags that deployed as a result of the crash. The SRS was controlled by a single point sensing and diagnostic module located within the occupant compartment. The driver air bag, **Figure 8**, was designed in the typical manner and housed in an H-configuration module located in the center of the steering wheel rim. The cover flaps opened at the designated tear points and were not damaged. There was no evidence of occupant contact to the flaps. The driver air bag measured 59 cm (23 in) in diameter in its deflated state. It was tethered by two internal straps sewn to the face of the bag. There were no external vent ports. The bag vented internally back through the module. The only evidence of contact to the air bag was a post-crash blood stain. The blood pattern began at the perimeter seam and extended to the center of the bag in its 12 o'clock sector. The front right passenger air bag was a mid-mount design located in the right aspect of the instrument panel and had properly deployed as a result of the crash.

Figure 8: Driver air bag.

DRIVER DEMOGRAPHICS

Age/Sex:	41 year old/Male
Height:	193 cm (76 in)
Weight:	106 kg (234 lb)
Restraint Use:	Integrated manual 3-point lap and shoulder belt
Usage Source:	NASS inspection, observation of the first responders
Mental/Physiological Condition:	Alcohol impaired, BAC 0.19
Medical Outcome:	Pronounced dead at the scene

DRIVER INJURY

Injury	Severity (AIS 98 Update)	Injury Mechanism
Focal cortical contusions involving the frontal lobes bilaterally	Serious (140602.3,3)	Front windshield and header backed by the rear of the semi-trailer
5 cm (2 in) laceration at the right lateral aspect of the right lobe of the liver extending 2.5 cm (1 in) into the parenchyma	Moderate (541822.2,1)	Steering wheel rim
10 cm (4 in) subscalpular hemorrhage	Minor (190402.1,5)	Front windshield and header backed by the rear of the semi-trailer
Confluent area of facial abrasion and laceration involving the right aspect of the forehead extending from the eyebrow level to the vertex of the head	Minor (290202.1,7) Minor (290602.1,7)	Front windshield and header backed by the rear of the semi-trailer
Multiple abrasions of the lower extremities, bilaterally	Minor (890202.1,3)	Knee bolster

DRIVER KINEMATICS

Immediately prior to the crash, the restrained driver of the Dodge was seated with an unknown posture with his seat adjusted to a rear seat track position consistent with his stature. The vehicle was traveling at approximately 121 to 129 km/h (75 to 80 mph). The Dodge impacted the rear of the tractor/semi-trailer resulting in a delta V of approximately 37 to 45 km/h (23 to 28 mph). The force of the impact caused the deployment of the vehicle's Supplemental Restraint System. The driver responded to the 12 o'clock direction of the impact force by initiating a forward trajectory.

The driver loaded the 3-point integrated restraint and began to ride-down the crash forces. As the driver loaded the restraint, the increasing belt forces were reacted by turning loop and retractor mounted to the seat back. Due to the compliant structure of the seat back, the loading of the shoulder restraint caused the seat back to deflect forward. This in-turn allowed the driver to translate further forward into fuller contact with the driver air bag and the forward structures of the interior. Coincident to his forward translation, the vehicle's windshield and header, instrument panel and toe pan intruded into the driver's interior space due to the exterior crash forces. Instead of "shared restraint" between the seat belt and driver air bag, the

driver air bag had to contribute a larger component of the driver's restraint. As a result, the driver's chest loaded and bottomed out the bag. The driver's abdomen loaded and deformed the steering wheel rim resulting in a liver laceration. The inertia of the head caused the neck to flex forward and the driver's head contacted the intruded windshield and header. This contact resulted in a large area abrasion and laceration of the forehead and fatal cerebral contusions. Analysis of the crash has determined the driver's fatal injuries were the result of the reduced effectiveness of the integrated restraint system that occurs in a severe crash, coupled with the severe intrusion into the driver's interior space.