**TRANSPORTATION SCIENCES**
**Crash Research Section**

Veridian Engineering
Buffalo, New York

# CALSPAN LIMITED ON-SITE REDESIGNED AIR BAG INVESTIGATION
# VERIDIAN CASE NO. CA98-16
# VEHICLE: 1998 DODGE DAKOTA SPORT PICKUP TRUCK
# LOCATION: MICHIGAN
# CRASH DATE: JANUARY 1998

Contract No.
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Washington, D.C. 20590

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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 are 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.

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16. *Abstract*

This limited on-site investigation focused on the performance of the redesigned frontal air bag system in a 1998 Dodge Dakota Sport pickup truck. The redesigned air bags deployed as a result of the vehicle's severe frontal impact against the rear of a semi-trailer linked to a 1988 Ford LTL-9000 tractor. The vehicles were traveling westbound on an interstate roadway when the driver of the Dodge presumably fell asleep and impacted the back of the semi-trailer resulting in severe frontal damage to the Dakota. In addition to the frontal air bags, the Dodge's air bag system was equipped with a shut-off switch for the front right air bag. The switch was in the on-position at the time of the crash and both the front left and front right redesigned air bags deployed. The driver of the Dodge was an unrestrained 21 year old male with a height of 178 cm (70 in) and weight of 70 kg (155 lb). He sustained a comminuted fracture of the right acetabulum with an adjacent fracture of the right ischium and a dislocation of the right femoral head, a full thickness laceration of the right forehead with a closed head injury and retrograde amnesia, a Grade 2 spleen laceration, a comminuted fracture of the right talas, ecchymosis with abrasion of the right knee, and an abrasion of the right hand. He was transported by ambulance to a trauma center and admitted for seven days for treatment of his injuries. The front left redesigned air bag provided adequate protection to the unbelted driver by preventing thoracic injury and minimizing the severity of his head and abdominal injuries.


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## *BACKGROUND*

This limited on-site investigation focused on the performance of the redesigned frontal air bag system in a 1998 Dodge Dakota Sport pickup truck. The redesigned air bags deployed as a result of the vehicle's severe frontal impact against the rear of a semi-trailer linked to a 1988 Ford LTL-9000 tractor. The vehicles were traveling westbound on an interstate roadway when the driver of the Dodge presumably fell asleep and impacted the back of the semi-trailer resulting in severe frontal damage to the Dakota **(Figure 1)**. In addition to the frontal air bags, the Dodge's air bag system was equipped with a shut-off switch for the front right air bag. The switch was in the on-position at the time of the crash and both the front left and front right redesigned air bags deployed. The driver of the Dodge was an unrestrained 21 year old male with a height of 178 cm (70 in) and weight of 70 kg (155 lb). He sustained a comminuted fracture of the right acetabulum with an adjacent fracture of the right ischium and a dislocation of the right femoral head, a full thickness laceration of the right forehead with a closed head injury and retrograde amnesia, a Grade 2 spleen laceration, a comminuted fracture of the right talas, ecchymosis with abrasion of the right knee, and an abrasion of the right hand. He was transported by ambulance to a trauma center and admitted for seven days for treatment of his injuries. The front left redesigned air bag provided adequate protection to the unbelted driver by preventing thoracic injury and minimizing the severity of his head and abdominal injuries.

**Figure 1. Overall view of the Dodge Dakota's damaged frontal plane.**

This January 1998 crash was identified through the General Estimates System (GES) and was subsequently assigned as a limited on-site redesigned air bag case to Calspan's Special Crash Investigation team on Wednesday, March 18, 1998. The Dodge Dakota remained available for an on-site investigation, therefore NHTSA authorized a local NASS researcher (PSU-11) to perform the vehicle inspection. The struck tractor-trailer combination was not available for inspection.

## *SUMMARY*

### *Crash Site*

The crash occurred during nighttime hours on a physically divided urban interstate roadway. The westbound segment of the interstate roadway consisted of three travel lanes that were straight and level with paved shoulders paralleling the inboard and outboard lanes. The travel lanes were artificially illuminated and the asphalt road surface was dry at the time of the crash. The posted speed limit was 89 km/h (55 mph).

***SUMMARY continued***

***Vehicle Data - Dodge Dakota***

The Dodge Dakota 4x2 Sport pickup truck was configured with a regular cab and short cargo bed on a 284.2 cm (111.9 in) wheelbase. The power train consisted of a conventionally mounted 3.9 liter V-6 gasoline engine linked to a 4-speed automatic transmission with a column mounted selector lever. The Dakota was identified by vehicle identification number (V.I.N.) 1B7FL26X0WS (production number omitted) with an approximate odometer reading of 11,000 km (7,000 miles) at the time of the crash. The bed of the Dakota was equipped with a post-manufacture tonneau cover. The Dakota was also equipped with power-assisted front disc/rear drum brakes with a rear-wheel anti-lock braking system (ABS).

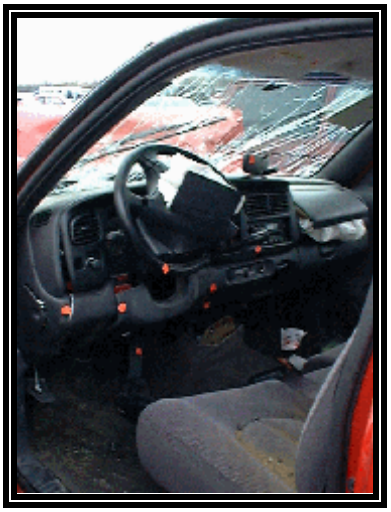

**Figure 2. Overall view of the Dakota's Interior.**

The interior of the Dakota was configured as a three passenger vehicle with a split-bench front seat **(Figure 2)** with separate back supports and integral head restraints for the outboard positions. The windows and seat were manually controlled and the steering column was fixed. The front outboard seated positions were equipped with three-point manual lap and shoulder belt systems with height adjusters. A lap belt was available for the center front position. The three-point belt systems consisted of a continuous loop webbing with locking latchplates and emergency locking retractors located in the lower B-pillars.

***Struck Tractor-Trailer***

The 1988 Ford tractor was a LTL-9000 Series (14.0 L, 855 CID), conventional cab equipped with a tandem rear axle. It was identified by V.I.N. 1FDZA90W9JVA (production number omitted). Data pertaining to the semi-trailer was not available, however it was probably equipped with an underride guard based on the damage pattern to the front of the Dakota.

***Crash Sequence***

**Pre-Crash**

The tractor-trailer combination was traveling in a westerly direction on the outboard lane of the divided interstate roadway at an estimated speed of 89 km/h (55 mph). The driver of the Dodge Dakota was also traveling westbound on the outboard lane at a police reported high rate of speed. As he continued westbound, the driver of the Dakota allowed his vehicle to drift off the right road edge onto the shoulder. He subsequently applied a clockwise steering input to redirect the vehicle onto the travel lane. The driver again allowed the Dakota to drift to the right as he approached the rear of the tractor-trailer. The driver steered left to redirect the vehicle onto the travel lane. As he completed this maneuver, his vehicle impacted the rear of the semi-trailer. The right side road departures were noted by the investigating officer in his narrative report.

*SUMMARY continued*

**Crash**

The frontal area of the Dodge Dakota impacted the rear left and center area of the semi-trailer. The direct contact damage extended across the full width of the Dakota, however, the crush profile resembled an off-set configuration from engagement against the suspected dock/underride guard. As the Dakota engaged against the rear of the semi-trailer, the frontal structure of the vehicle was displaced in an upward direction. The resultant directions of force were within the 12 o'clock sector for the Dakota and 6 o'clock for the struck tractor-trailer unit. The barrier equivalent application of the WinSMASH reconstruction program calculated the total delta V for this impact at 45.7 km/h (28.4 mph) with a longitudinal component of -45.7 km/h (-28.4 mph). This velocity change was sufficient to deploy the vehicle's redesigned frontal air bag system.

**Post-Crash**

The Dodge Dakota came to rest forward of the point of impact in the westbound travel lane while the tractor-trailer combination came to a controlled stop several hundred meters forward of the impact location. The driver of the Dakota remained in the vehicle and was removed by rescue personnel and transported to a local trauma center where he was evaluated and admitted for treatment of his injuries. The Dakota was towed from the scene of the crash due to disabling damage. The Ford tractor-semi-trailer was driven from the scene of the crash by its driver.

***Vehicle Damage***

**Dakota - Exterior**

The 1998 Dodge Dakota pick-up truck sustained severe frontal damage as a result of its impact with the back plane of the semi-trailer. The direct contact damage began at the front left bumper corner and extended 141.0 cm (55.5 in) to the right, across the full width of the bumper fascia. The damage extended vertically onto the grille and hood areas of the Dakota. Circular contact damage from the left rear tail lamps of the semi-trailer was evidenced at the front right hood area of the Dakota **(Figure 3)**. Maximum crush was located approximately 66.2 cm (26.0 in) inboard of the front left bumper corner and measured 67.1 cm (26.4 in) in depth. A crush profile was documented at bumper level and is reported in **Table 1** and identified in **Figures 3 and 4**. The damage resulted in a 12 o'clock direction of force with an incremental upward displacement of 20 assigned due to the vertical displacement of the left side frame rail. The resultant Collision Deformation Classification (CDC) was 32-FDEW-4 with the incremented value. The wheelbases were reduced on the left and right sides by 7.0 cm (2.8 in) and 6.0 cm (2.4 in), respectively.

**Table 1. 1998 Dodge Dakota Crush Measurements**

| Plane of Impact | Field L | C1 | C2 | C3 | C4 | C5 | C6 |
|---|---|---|---|---|---|---|---|
| Center of the rotated frontal bumper fascia. | 127 cm (50 in) | 12.0 cm (4.7 in) | 29.0 cm (11.4 in) | 48.0 cm (18.9 in) | 67.0 cm (26.4 in) | 51.0 cm (20.0 in) | 52.0 cm (20.5 in) |

*Vehicle Damage continued*

**Figure 3. Left three-quarter view of the Dakota.**

**Figure 4. Right three-quarter view of the Dakota.**

The driver had a flat left rear tire prior to the crash and replaced it with the spare tire. The flat tire and wheel rim were loosely placed in the cargo bed. At impact, the tire was displaced forward due to the 12 o'clock impact force and impacted the front wall of the bed which resulted in deformation to the back wall of the cab. Maximum crush to the cab wall was 31.0 cm (12.2 in).

***Interior***

The interior of the Dodge Dakota sustained moderate damage from intrusion and occupant contact. Intrusion damage was widespread throughout the Dakota's cab and included longitudinal displacement of the toepans, vertical displacement of the steering assembly, and forward displacement of the seatbacks and the back wall of the cab. The cab wall displacements resulted from loose cargo in the pickup box. Intruded vehicle components and their values are reported in **Table 2**.

**Table 2. 1998 Dodge Dakota Intruded Components and Measurements**

| Intruded Component | Location of Intrusion | Intruded Value | Dominant Crush Direction |
|---|---|---|---|
| Toe pan | Front left | 9.0 cm (3.5 in) | Longitudinal (rearward) |
| Toe pan | Front right | 15.0 cm (6.0 in) | Longitudinal (rearward) |
| Back cab panel | Front left | 3.0 cm (1.2 in) | Longitudinal (forward) |
| Back cab panel | Front center | 31.0 cm (12.2 in) | Longitudinal (forward) |
| Back cab panel | Front right | 28.0 cm (11.0 in) | Longitudinal (forward) |
| Seat back | Front left | ~ 6.0 cm (2.4 in) | Longitudinal (forward) |
| Seat back | Front right | ~ 10.0 cm (3.9 in) | Longitudinal (forward) |

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| Seat back | Front right | ~ 10.0 cm (3.9 in) | Longitudinal (forward) |

The unrestrained driver loaded the knee bolster and the steering assembly which resulted damage to the contacted components. His knees scuffed the rigid plastic bolster and displaced the steering column cover. The driver loaded through the deployed redesigned air bag and submarined the steering assembly which resulted in deformation of the wheel rim and compression of the energy absorbing column.

The upper steering wheel rim (rotated 180 degrees at crash) sustained 8.5 cm (3.3 in) of forward deformation. The back aspect of the steering wheel hub and the lower portion of the steering wheel rim were in contact with the left upper instrument panel which resulted from occupant loading. The left and right sheer capsules were displaced by approximately 5.1 cm (2.0 in) and 4.0 cm (1.6 in) respectively **(Figure 5)**. The energy absorbing steering column was compressed approximately 3.5 cm (1.4 in).

**Figure 5. Left and right sheer capsules.**

### *AUTOMATIC RESTRAINT SYSTEM - REDESIGNED*

The Dakota was equipped with a frontal air bag system which consisted of a single point control module, front left and front right air bag modules with redesigned inflator units, a front right air bag shut-off switch, and an instrument panel mounted air bag indicator lamp. Air bag warning labels were present on the exposed (when stowed against the headliner) aspect of the sunvisors.

*AUTOMATIC RESTRAINT SYSTEM - REDESIGNED continued*

The front right air bag shut-off switch was located in the lower aspect of the center instrument panel **(Figures 6 and 7)**. The switch was in the on-position at the time of the crash which resulted in deployment of the front right air bag.

**Figure 6. Center instrument panel and highlighted shut-off switch for the Dodge Dakota.**


**Figure 7. Close-up view of an exemplar shut-off switch for the right front air bag of a 1998 Dodge Dakota.**

The front left air bag was housed in the 4-spoke steering wheel hub and was concealed by asymmetrical H-configuration cover flaps. The upper cover flap had a total width of 15 cm (6 in) at the horizontal tear seam and a height of 10 cm (4 in). The lower cover flap shared the same width and was approximately 2.5 cm (1.0 in) in height. A faint abrasion pattern was evident on the lower aspect of the upper cover flap. The front left air bag measured 66 cm (26 in) in diameter in its deflated state and was tethered by two internal straps **(Figure 8)**. The nylon air bag was not equipped with vent ports. A blood stain was located on the upper left quadrant of the air bag on and adjacent to the peripheral seam. The blood extended onto the face and back side of the air bag and measured 7.0 cm (2.8 in) in width and 3.0 cm ( 1.2 in) in height. There was no direct contact evidence to the air bag membrane from expansion within the air bag module cover flaps during deployment, or from driver loading.

**Figure 8. Deployed front left redesigned air bag.**

The front right air bag was housed in the mid-instrument panel. The single module cover flap was 33 cm

(13 in) in width and 23 cm ( 9 in) in height. A blood stain was located on the lower and center aspects of the module cover flap. The front right air bag had a measured height of 57 cm (22 in) and was not equipped with vent ports or tethers. Blood transfers were located on the left side of the air bag from driver contact post-crash.

## *DRIVER DEMOGRAPHICS*

### *Dodge Dakota*

| | |
|---|---|
| Age/Sex: | 21 year old male |
| Height: | 178 cm (70 in) |
| Weight: | 70 kg (155 lb) |
| Manual Restraint Usage: | None |
| Usage Source: | Vehicle inspection |
| Mode of Transport From Scene: | Ambulance |
| Type of Medical Treatment: | Transported to a trauma hospital where he was evaluate and admitted for surgical treatment of his fractures |
| Length of Hospitalization: | 7 days |

## *DRIVER INJURIES*

| Injury | Injury Severity (AIS 90) | Injury Mechanism |
|---|---|---|
| Complex and comminuted fracture of the right acetabulum with dislocation of the posterior and superior femoral head and a fracture of the right ischium | Serious (852604.3,1) | Induced fracture from knee loading against the knee bolster |
| Comminuted fracture of the trochlear process of the right talas on the lateral aspect | Moderate (853200.2,1) | Intruding toe pan/brake pedal |
| Grade II spleen laceration | Moderate (544212.2,2) | Lower steering wheel rim |

***DRIVER INJURIES continued***

| | | |
|---|---|---|
| Closed head injury with retrograde amnesia (conscious at scene) | Moderate (160410.2,0) | Rear view mirror |
| Full thickness laceration of the right forehead | Minor (290602.1,7) | Rear view mirror |
| Ecchymosis of the right knee with abrasion | Minor (890402.1,1; 890202.1,1) | Knee bolster |
| Abrasion over the left hand | Minor (790202.1,2) | Left door window frame/left A-pillar |

***DRIVER KINEMATICS***

The driver of the Dodge Dakota was wearing a black leather jacket over a long sleeved shirt and pants at the time of the crash which occurred during cold temperatures. He was seated in a presumed upright posture with the seat track adjusted to a rear position. The driver was not wearing the manual 3-point lap and shoulder belt system. The lack of belt usage was determined from the contact evidence within the vehicle, driver statements, and observations of the investigating officer and emergency medical technicians at the scene of the crash. The hospital medical records identified his BAC at 0.01 and a positive result for cannabinoids.

The redesigned frontal air bag system deployed as a result of the impact against the rear of the semi-trailer. The impact displaced the frontal structure of the pickup truck in an upward direction which allowed the driver to move on a path that was parallel to the ground resulting in lower contact to frontal components. Due to the engagement against the rear of the semi-trailer, the Dakota's steering wheel rotated approximately 165 degrees in a CCW direction. The expanding front left air bag initially contacted the left forearm of the driver resulting in a fling injury (abrasion) of the left hand from contact against the left door window frame and A-pillar.

The unrestrained driver initiated a forward trajectory in response to the frontal impact force **(Figure 9)**. He initially loaded the deployed front left air bag with his chest which protected his chest from injury. There was no contact evidence on the air bag, however, a blood stain was noted on the upper left quadrant. Due to the severity of the crash and the vertical displacement of the frontal structure, the driver partially submarined the steering assembly. His abdominal area compressed the lower aspect of the air bag and loaded through the redesigned air bag, engaging against the lower steering wheel rim. This contact resulted in a Grade II spleen laceration. The loading force deformed the wheel rim forward 8.5 cm (3.3 in) and compressed the shear capsules 5 cm (2 in) and 4.0 cm (1.6 in) for the left and right sides, respectively.

**Figure 9. Driver trajectory and contact points within the vehicle.**

***DRIVER KINEMATICS continued***

The driver's knees contacted the knee bolster which resulted in ecchymosis with abrasion over the right knee. Loading evidence on the bolster consisted of scuff marks and fractures of the plastic component. The loading force was transmitted through the femur which resulted in a complex and comminuted fracture of the right acetabulum with dislocation of the posterior and superior femoral head and a fracture of the right ischium.

His right foot loaded against the intruding toe pan and brake pedal which resulted in a comminuted fracture of the trochlear process of the right talas. The rubber brake pedal pad was scuffed and separated from the pedal assembly.

Following his initial trajectory, the driver moved laterally to his right and contacted the rear view mirror. The NASS researcher noted a tissue transfer to the mirror and separation of the mirror from its swivel mount. The driver's head contacted the mirror which lacerated his right forehead. He was diagnosed with a closed head injury with retrograde amnesia. The driver stated he lost consciousness, however, he was found conscious at the scene by rescue personnel.

The driver subsequently slumped to his right against the deployed redesigned right front air bag. Blood stains were noted to the left aspect of the front right air bag and the module cover flap. The driver continued to the right and came to rest in a slumped position across the floor area of the vehicle.