TRANSPORTATION SCIENCES
CRASH DATA RESEARCH CENTER

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ADVANCED OCCUPANT PROTECTION SYSTEM STUDY
2000 FORD TAURUS INVESTIGATION

VERIDIAN CASE NO. CA00-043

LOCATION - MICHIGAN

CRASH DATE - AUGUST 2000

Contract No. DTNH22-94-07058

Prepared for:

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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 on-site investigation focused on the performance of the Advanced Occupant Protection System (AOPS) in the 2000 Ford Taurus. The AOPS consisted of the integrated use of 3-point lap and shoulder belts with load limiter retractors, seat belt buckle pre-tensioners, driver seat position sensing and dual-stage frontal air bags. The driver and front right passenger air bags were designed to deploy at different thresholds based on crash severity, restraint use, and seat position (driver only). The subject 2000 Ford Taurus was involved in an intersection type crash with a 1999 Dodge Stratus. The frontal air bags in the Ford Taurus deployed as a result of the crash. The 85 year old female driver of the Ford was restrained at the time of the crash by the vehicle's 3-point lap and shoulder belt. She suffered fractures of the left wrist and left ankle, and was transported to a local hospital.

This crash was identified through the weekly sample of the Michigan police jurisdictions conducted by the General Estimates System (GES). The Michigan GES site informed NASS Zone Center 1 of this crash, which in-turn notified the Crash Investigations Division of the National Highway Traffic Safety Administration (NHTSA). NHTSA assigned an on-site investigation of the crash to the Special Crash Investigations team at Veridian Engineering as part of the Advanced Occupant Protection System Study. Specifically, the SCI team was instructed to download the crash data stored in the Restraint Control Module as a supplement to the crash investigation.

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ADVANCED OCCUPANT PROTECTION SYSTEM STUDY
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BACKGROUND

This on-site investigation focused on the performance of the Advanced Occupant Protection System (AOPS) in the 2000 Ford Taurus. The AOPS consisted of the integrated use of 3-point lap and shoulder belts with load limiter retractors, seat belt buckle pre-tensioners, driver seat position sensing and dual-stage frontal air bags. The driver and front right passenger air bags were designed to deploy at different thresholds based on crash severity, restraint use, and seat position (driver only). The subject 2000 Ford Taurus was involved in an intersection type crash with a 1999 Dodge Stratus. The frontal air bags in the Ford Taurus deployed as a result of the crash. The 85 year old female driver of the Ford was restrained at the time of the crash by the vehicle's 3-point lap and shoulder belt. She suffered fractures of the left wrist and left ankle, as a result of the crash, and was transported to a local hospital.

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SUMMARY

Crash Site

This two-vehicle crash occurred during the afternoon hours in August, 2000. It was daylight at the time of the crash and the weather was clear. The road surface was dry. At the crash scene, the primary roadway was a five lane north/south road. The road was configured with two travel lanes in either direction and with a common center turn lane. A two-lane east/west private driveway intersected from the east forming a three-leg intersection. The driveway served as the entrance/exit into a parking area for a shopping plaza. The intersection was controlled by a stop sign for traffic exiting the parking lot. The speed limit in the area of the crash was 72 km/h (45 mph). **Figure 1** is a southbound trajectory view. Note, the construction zone was not present at the time of the crash.

Figure 1: Southward trajectory view near the point of impact.

Pre-Crash

The 2000 Ford Taurus was southbound driven by an 85 year old restrained female. The vehicle was in the center turn lane and it was the driver's intention to turn left into the shopping plaza parking lot on the east side of the road. The 1999 Dodge Stratus was northbound in the inboard (left) lane. This vehicle was driven by a 17 year old restrained male. The driver of the Taurus failed to detect the northbound Stratus and initiated a left turn across the vehicle's path. The driver of the Dodge probably steered clockwise (right) in an attempt to avoid the impact.

Crash

The crash occurred when the forward aspect of the Ford's right side was struck by the left frontal area of the Dodge in a 02/11 o'clock impact configuration, **Figure 2**. The force of the impact caused the deployment of the frontal air bag systems of both vehicles. The lateral impact of the Dodge, forward of the Ford's center of gravity, caused the Ford to rotate counterclockwise. The pre-crash steering of the Dodge coupled with the lateral momentum of the Ford caused the Dodge to rotate clockwise. As the respective vehicles rotated away from the initial impact, the left side of the Dodge impacted the right rear side of the Ford in a secondary side slap. The vehicles then came to rest in the northbound lanes of the roadway. Their exact final rest positions were unknown and not documented by the police investigation. Inspection of the crash scene, at the time of the on-site investigation, was unremarkable. Due to the delayed crash notification, any physical evidence of the crash at the scene had deteriorated. The total delta V's of the impact as calculated by the Missing Vehicle algorithm of the WINSMASH model were 31.2 km/h (19.4 mph) and 33.5 km/h (20.8 mph) for the Ford Taurus and Dodge Stratus, respectively.

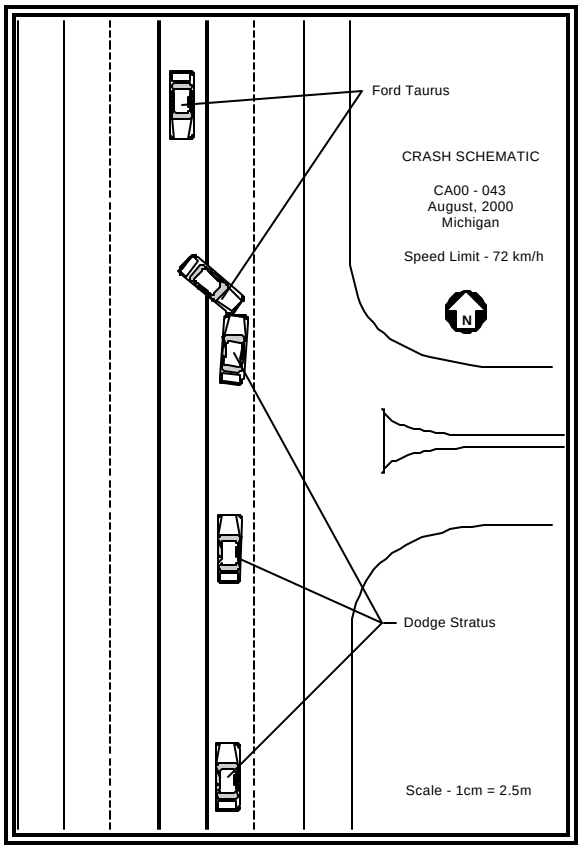


Figure 2: Crash schematic.

Post-crash

The police and EMS personnel responded to the scene. The restrained driver of the Dodge Stratus was not injured and did not require medical treatment. The restrained driver of the Ford sustained a police reported non-incapacitating injury. She was transported to a local hospital for treatment of her injuries. A follow-up interview with her insurance company determined she sustained a left wrist fracture and a left ankle fracture, as a result of the crash.

2000 FORD TAURUS

The 2000 Ford Taurus was identified by the Vehicle Identification Number (VIN): 1FAFP53U2YG (production sequence deleted). The vehicle's power train consisted of a 3.0 liter, V-6 engine linked to a 4-speed automatic overdrive transmission. The vehicle had 4-wheel disc brakes. It was not ABS equipped. The cloth trimmed interior was equipped with a power package that included power steering, brakes windows, door locks, and mirrors. The 4-door sedan was manufactured in November 1999. The vehicle's odometer read 1,236 km (768 miles) at the time of the inspection.

Primary Exterior Damage

The vehicle was in a state of repair at the time of the SCI investigation. Reportedly, the frame had been partially straightened. **Figures 3 and 4** are right side and right front close-up views of the damaged vehicle. The forward aspect of the Taurus's right side sustained 54.6 cm (21.5 in) of direct contact damage, as a result of the initial impact. The direct contact began 30.5 cm (12.0 in) forward of the right front axle and extended forward to the right corner of the front bumper. This direct damage pattern wrapped around the corner an additional 16.5 cm (6.5 in). The force of the lateral impact to the front bumper shifted the vehicle's front clip (vehicle structure forward of the cowl) to the left. The operation of the left front door was restricted. There were no glass fractures. There was no measurable change in the wheelbase dimensions. Vehicle crush measurements were not taken, as the vehicle had been partially repaired and its crush profile had been altered. The Missing Vehicle algorithm of the WINSMASH model calculated a total delta V of 31.2 km/h (19.4 mph). The longitudinal and lateral delta V components were -15.6 km/h (9.7 mph) and -27.0 km/h (16.8 mph), respectively. The estimated Collision Deformation Classification (CDC) was 02-RFEW-2.

Figure 3: Right side view of the Taurus.

Figure 4: Close-up view of the right front damage.

Secondary Exterior Damage

The exterior damage resultant to the secondary side slap was confined to the right rear quarterpanel of the Taurus. The direct contact damage measured 71.1 cm (28.0 in). This damage began 41.9 cm (16.5 in) rearward of the right rear axle and extended to the right rear corner. The crush profile was approximately

triangular when viewed from above. The maximum lateral deformation measured 10.2 cm (4.0 in) at C1, the right rear corner location, and tapered to zero crush over the 94 cm (37 in) Field L. The impact displaced the trunk lid to the left, hampering the proper operation of the latch. The CDC of this impact was 03-RBEW-1.

1999 DODGE STRATUS

The 1999 Dodge Stratus was identified by the Vehicle Identification Number (VIN): 1B3EJ46X5XN (production number deleted). The 4-door sedan was equipped with a 2.4 liter, I-4 engine linked to a 4-speed automatic transmission. The safety systems included manual 3-point lap and shoulder belts for the four outboard seat positions and a frontal air bag system for the driver and front right passenger. The vehicle was located in a salvage yard at the time of the inspection and considered a total loss by its insurance company.

Primary Exterior Damage

Figure 5 is a front view of the Stratus. The direct contact damage to the front of the Dodge measured 49.0 cm (19.3 in) in width. The direct damage began 24.9 cm (9.8 in) left of center and extended to the left front bumper corner. The combined direct and induced damage extended across the vehicle's entire 147 cm (58 in) frontal end width. The crush profile measured along the bumper reinforcement bar was as follows: C1=35.9 cm (14.1 in), C2=29.2 cm (11.5 in), C3=24.1 cm (9.5 in), C4=19.9 cm (7.9 in), C5=14.0 cm (5.5 in), C6=9.3 cm (3.7 in). The hood buckled rearward and contacted the windshield, fracturing the left lower aspect of the laminate. There was no measurable change in the wheelbase dimensions. The total delta V calculated by the WINSMASH model calculated a damage based delta V of 33.5 km/h (20.8 mph). The Collision Deformation Classification was 11-FLEW-2.

Figure 5: Frontal view of the Dodge.

Secondary Exterior Damage

The secondary side slap damage on the Dodge was confined to the left rear quarterpanel. The width of the direct contact measured 54.1 cm (21.3 in). The damage began 9.7 cm (1.5 in) forward of the left rear axle and ended 57.9 cm (22.8 in) rearward of the left rear axle. The maximum lateral deformation measured 7.6 cm (3.0 in) and was located 30.7 cm (12.1 in) rearward of the axle. The localized nature of the damage was consistent with the secondary Taurus damage. The CDC of this impact was 09-LBEW-1.

2000 FORD TAURUS

Advanced Occupant Protection System

The Advanced Occupant Protection System in the 2000 Ford Taurus, designated by the manufacturer as the Personal Safety System (PSS), was a total redesign from earlier model years. The AOPS consisted of the integrated use of manual 3-point lap and shoulder belts with load limiting retractors, buckle pre-tensioners, driver seat position sensing and dual-stage air bag inflation. Additionally , the driver and front right passenger air bags were designed to deploy at different thresholds of crash severity on restraint use and seat position (driver only). The Restraint Control Module (RCM) located on the vehicle's centerline, under the instrument panel, monitored and controlled the deployment of the vehicle's safety systems. The RCM was capable of recording data related to the crash event. The crash data was downloaded in the field during the SCI inspection. This data was then electronically forwarded to the Safety Office of the Ford Motor Company for analysis. The results of the downloaded data are included as **Attachment A** at the end of this report.

The RCM data indicated the driver's belt system was buckled and the buckle pre-tensioner fired 62 milliseconds after algorithm initiation. The frontal air bags deployed with a Stage 1 inflation at 62 milliseconds. The driver seat was adjusted to a forward position. The RCM sensed and recorded the crash acceleration pulse for a duration of 78 milliseconds. The 78 millisecond longitudinal delta V recorded by the RCM was approximately -30.7 km/h (-12.1 mph). The 78 millisecond lateral delta V was approximately -49.0 km/h (-19.3 mph). Examination of the acceleration and velocity curves indicated both traces were still active at the end of the recording. Therefore, only a portion of this long duration crash pulse was captured by the recording.

The Taurus was equipped with 3-point lap and shoulder belt systems in the front outboard seat positions. The front seat belt systems consisted of a continuous loop lap and shoulder belt webbing with a sliding latch plate. The vehicle sensitive/load limiting retractors were located in the base of the B-pillars. The front restraints were also equipped with buckle mounted pre-tensioners. The restraint's D-rings were adjustable. The rear seat was equipped with 3-point lap and shoulder restraints for all three seat positions.

Upon inspection, the driver's restraint webbing was stowed within the retractor and the retractor was operational. The left front D-ring was adjusted to the full up position. There was very minor evidence on the latch plate of historical use, however, this was consistent with the vehicle's mileage. Transfer marks indicative of restraint use were noted to both the D-ring surface and the plastic surface of the turning loop at the latch plate. The driver's buckle pre-tensioner had fired. The post-crash measurement of the pre-tensioner's piston barrel was 64 mm (2.5 in). The pre-crash specification of the barrel length was 110 mm (4.3 in), therefore the fired pre-tensioner removed 46 mm (1.8 in) of slack from the belt system. All the evidence identified during the inspection indicated the driver was properly restrained at the time of the crash.

There was no intrusion or interior damage associated to the exterior forces of the crash. The vehicle's interior damage was related to the deployment of the frontal air bags and the specific occupant contact

points. Examination of the driver's knee bolster identified a 13 cm (5 in) scuff from contact by the right lower extremity. The scuff started on the steering column center line and was directed to the right. A 2 cm x 5 cm (1 in x 2 in) abraded scuff was identified on the headliner and overlapped onto the outboard corner of left sun visor. This contact resulted from a possible fling contact of the left arm caused by the deploying driver air bag.

The driver seat was adjusted to a rear track position at inspection. This was not the seat's at-crash adjustment. The vehicle was in a state of repair and was being driven in the repair facility by the mechanics. The seat was probably in a forward track position at the time of the crash as determined by the AOPS RCM. The forward seat adjustment was probably consistent with the stature of the driver considering her advanced age. The driver's height and weight were unknown.

There was no deformation of the steering wheel rim. Inspection of the steering column shear capsules determined there was no shear capsule separation. The bend bracket supporting the mid-aspect of the steering column and the shear coupling on the lower aspect of the column were intact.

The driver air bag module was designed in the typical manner in the center of the steering wheel. The driver air bag (**Figure 6**) had deployed from the H-configuration module cover flaps. The cover flaps opened along the designated tear seams. The height of the upper and lower flaps measured 6.4 cm (2.5 in) and 4.6 cm (1.8 in), respectively. The width of the flaps measured 17.2 cm (6.8 in). There was no contact evidence on the cover flaps. The deployed driver air bag measured 53 cm (21 in) in diameter. It was tethered by four straps sewn to the face of the bag. The bag was vented by two 2.9 cm (1.1 in) ports located in the 10/2 o'clock position on the back side of the bag. A beige make-up transfer was identified on the face of the bag in the 2 o'clock sector. The transfer covered an area that measured approximately 10.2 cm x 8.9 cm (4.0 in x 3.5). Two faint red lipstick marks were located within the transfer, near the perimeter of the bag. The lipstick transfers measured 2.0 cm (0.8 in) in length. The following nomenclature identified the air bag:

P5206000-00D TXM 99307033

Figure 6: View of the driver air bag.

The front right passenger air bag module was a top mount design located in the right aspect of the instrument panel. The air bag had deployed as designed from the module. The face of the deployed passenger bag measured 58.4 cm x 39.4 cm (23.0 in x 15.5 in), width by height, and extended 46 cm (18 in) from the aft edge of the module. A series of vertical vinyl transfers were located on the lower central aspect of the face of the bag. These transfer marks resulted from contact between the air bag and the rear

edge of the module during the deployment sequence. This transfer pattern had been identified on several other Ford Taurus AOPS investigations and was typical of this system's deployment. Further inspection of the passenger air bag was unremarkable. No evidence of occupant contact was identified.

DRIVER DEMOGRAPHICS

Age/Sex:	85 year old/Female
Height/Weight:	Unknown
Restraint Use:	3-point lap and shoulder belt
Usage source:	SCI inspection, RCM
Medical treatment:	Transported and admitted to a local hospital

DRIVER INJURY

Injury	Severity (AIS Update 98)	Injury Mechanism
Left wrist fracture, NFS	Moderate (751800.2,2)	Unknown (Refer to kinematics below)
Left ankle fracture, NFS	Moderate (852002.2,2)	Impact loading to the toe pan

Note: The above injuries were identified through an interview with the insurance carrier handling the Ford Taurus claim. The driver was unavailable for an interview.

DRIVER KINEMATICS

Immediately prior to the crash, the restrained 85 year old female driver was seated in a forward track position with a presumed normal posture. She steered the vehicle counterclockwise as she initiated a left turn directly into the path of the Dodge Stratus. At impact, the crash force caused the driver seat belt pre-tensioner to fire and deployed the frontal air bags.

The driver responded to the 02 o'clock direction of the impact by initiating a forward and right trajectory. The driver's right knee contacted the bolster evidenced by the scuff mark and she loaded her left leg which was probably braced on the toe pan. The impact loading of her left leg resulted in the ankle fracture. The driver's forward trajectory caused her to fully load the locked seat belt system with her torso and pelvis. This belt loading was evidenced by transfer marks to the surfaces of the D-ring and latch plate turning loop. The forward inertia of the head caused the neck to flex forward and the driver's face contacted the inflated driver air bag evidenced by the make-up transfer. This contact did not result in a reported injury. As the vehicles contacted in the secondary side slap, the driver initiated a rightward trajectory in response to the 03 o'clock direction of the impact. The proper use of the 3-point lap and shoulder belt effectively restrained the driver and maintained her position within the seat.

Two possible sources for the left wrist fracture were investigated. At impact, the vehicle was in a turning maneuver, hence the steering wheel was rotated counterclockwise. The force of the lateral impact probably caused the front wheels to rotate clockwise and may have wrenched the steering wheel from the driver's left hand. The wrist fracture may have occurred at this time. The steering wheel had to return to the 12 o'clock position (straight ahead) because the driver contacted the 02 o'clock sector of the air bag, consistent with her trajectory. Alternatively, the deploying driver air bag may have displaced the left arm from the steering wheel and into contact with the headliner evidenced by the abraded scuff. In this scenario the fracture occurred due to an impact load to the headliner, indirectly caused by the deploying driver air bag.

ATTACHMENT A

CA00-043.hex

2000 Taurus/Sable EDR Report - Summary Page

Investigation Data

File Name:	CA00-043.hex	File Save Date:	10-Nov-2000
File Read-out Date:	N/A	Report Date:	11-Dec-2000
Report Version:	1.6		

EDR Control Module Data

Data Validity Check:	Valid	EDR Model Version:	141
Time From Side Safing Decision to Left (Driver) Side Bag Deployment:			Not Deployed
Time From Side Safing Decision to Right (Passenger) Side Bag Deployment:			Not Deployed
Passenger Airbag Switch Position During Event:			N/A
Diagnostic Codes Active When Event Occurred:			0

Algorithm Times (Actual initiation depends on restraint system status (below).	ms
Time From Algorithm Wakeup to Pretensioner:	62
Time From Algorithm Wakeup to First Stage - Unbelted:	62
Time From Algorithm Wakeup to First Stage - Belted:	0
Time From Algorithm Wakeup to Second Stage:	0

Restraint System Status

Driver Seat Belt Buckle:	Engaged
Passenger Seat Belt Buckle:	Not Engaged
Driver Seat Track In Forward Position:	Yes
Passenger Seat Weight Switch Position:	N/A

Deployment Initiation Attempt Times	Driver	Passenger
Time From Algorithm Wakeup to Pretensioner Deployment Attempt:	62	Unbelted
Time From Algorithm Wakeup to First Stage Deployment Attempt:	62	62
Time From Algorithm Wakeup to Second Stage Deployment Attempt:	Disposal	Disposal

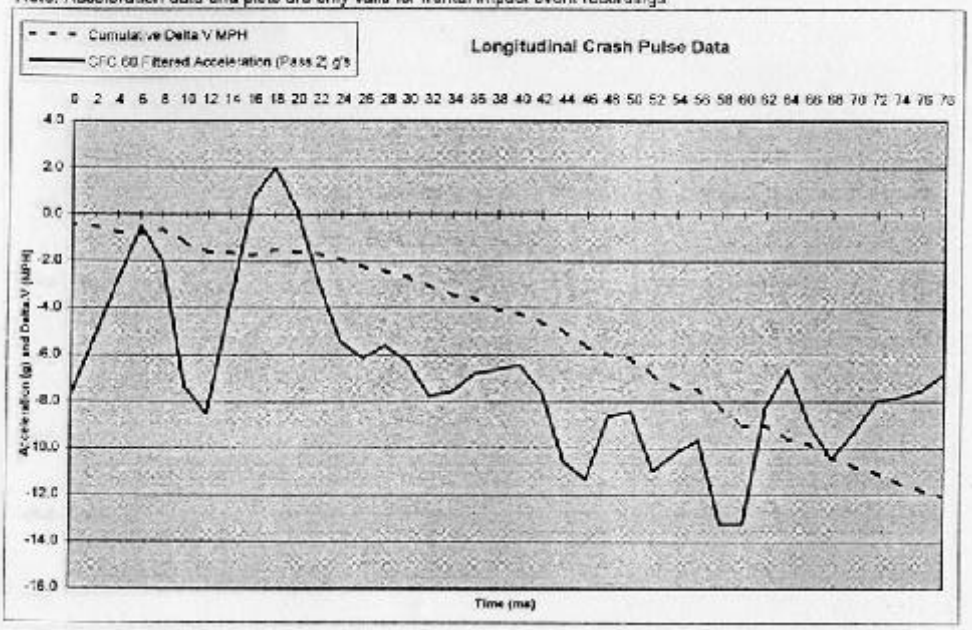
Notes

1. Read-out date is set by the PC interface tool.
2. Features and data parameters which are not available on the module are marked "N/A".
3. CFC 60 is a Butterworth 4-pole phaseless digital filter. (See SAE J211 Part 1 Appendix C dated March 1995.)
4. Total and maximum Delta-V results are not available from truncated/incomplete crash pulses.
5. Algorithm wakeup (0 ms) is not the first moment of vehicle contact or impact.
6. The Excel "Analysis ToolPak" Add-in must be enabled for this spreadsheet to operate properly.
7. Acceleration data and plots are only valid for frontal impact event recordings.

Longitudinal Cumulative Delta-V

Time (ms)	0	10	20	30	40	50	60	70	78
Delta-V (MPH)	-0.4	-1.2	-1.6	-2.7	-4.2	-6.1	-8.0	-10.8	-12.1

Note: Acceleration data and plots are only valid for frontal impact event recordings



Lateral Cumulative Delta-V

Time (ms)	0	10	20	30	40	50	60	70	78
Delta-V (MPH)	0.2	-0.7	-2.0	-3.4	-5.6	-8.7	-13.3	-17.1	-19.3

Note: Acceleration data and plots are only valid for frontal impact event recordings