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Veridian Engineering
Buffalo, New York 14225

ADVANCED OCCUPANT PROTECTION SYSTEM STUDY
2000 FORD TAURUS INVESTIGATION

VERIDIAN CASE NO. CA01-022

LOCATION - VIRGINIA

CRASH DATE - JANUARY 2001

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 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 diver seat position. The vehicle was also equipped with side impact air bags for the front occupants. The subject 2000 Ford Taurus ran off the right side of the road and impacted a tree with its forward left side. The force of the crash fired the driver buckle pretensioner, both frontal air bags and the left side impact air bag. The 48 year old female driver of the vehicle was restrained by the vehicle's 3-point lap and shoulder belt and sustained bilateral femur fractures as a result of the impact. She was admitted to a regional trauma center for treatment.

The Crash Investigations Division of the National Highway Traffic Safety Administration (NHTSA) was informed of the crash on February 15, 2001 by the police agency responsible for the investigation. NHTSA subsequently 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. The crash data stored in the vehicle's Restraint Control Module was downloaded as a supplement to the crash investigation.

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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 driver seat position. The vehicle was also equipped with side impact air bags for the front occupants. The subject 2000 Ford Taurus ran off the right side of the road and impacted a tree with its forward left side. The force of the crash fired the driver's buckle pretensioner, both frontal air bags and the left side impact air bag. The 48 year old female driver of the vehicle was restrained by the vehicle's 3-point lap and shoulder belt and sustained bilateral femur fractures as a result of the impact. She was admitted to a regional trauma center for treatment.

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SUMMARY

Crash Site

This single vehicle crash occurred during the afternoon hours in January, 2001. At the time of the crash, it was daylight and the weather was not a factor. The road surface was dry. At the crash scene, the road was configured with two lanes, north/south in direction. **Figure 1** is a southbound trajectory of the Ford Taurus. The road was straight with a positive grade on the approach to the crash scene and then changed to a sharp left curve with a negative grade. The radius of the curve measured approximately 99 m (325 ft). The west (right side) road shoulder was grass and sloped away from the traffic lanes. A school bus stop warning sign was located in the curve approximately 2.1 m (6.9 ft) from the road edge. The point of impact was a 51

Figure 1:Pre-crash trajectory view of the Ford.

cm (20 in) diameter tree that bordered the road. It was located approximately 30 m (100 ft) south of the curve and 1.6 m (5.3 ft) from the road edge. The speed limit in the area of the crash was 56 km/h (35 mph).

Pre-crash

The 2000 Ford Taurus was southbound driven by a 48 year old restrained female. She was the vehicle's sole occupant. As the vehicle approached the crash scene, the driver failed to negotiate the left curve and departed the west (right) side of the road. The right aspect of the vehicle's front bumper struck and sheared the wooden post of a warning sign during its early off-road trajectory. The vehicle's trajectory was defined by a right side rotating tire track through the earth/grass of the shoulder. The track was identified during the SCI inspection of the crash scene. As the vehicle continued southwestward off the road, the driver attempted to correct its trajectory by steering left. The vehicle's maximum lateral position off the road measured approximately 3 m (10 ft). Prior to regaining the road, the driver then steered back to the right.

Crash

The crash occurred with the forward left side of the Taurus striking a 51 cm (20 in) diameter tree. The left side of the Taurus, in the area of the left front axle, struck the tree in an 11 o'clock impact configuration. The total delta V of the crash calculated by a WINSMASH analysis was 37.0 km/h (23.0 mph). The longitudinal and lateral components were -32.1 km/h (-19.9 mph) and 18.5 km/h (11.5 mph), respectively. The vehicle rotated clockwise approximately 45 degrees and came to rest in contact with the tree, facing westward. The force of the crash caused the driver's buckle pretensioner to fire and deployed the frontal air bags and the left side impact air bag. **Figure 2** is a schematic of the crash.

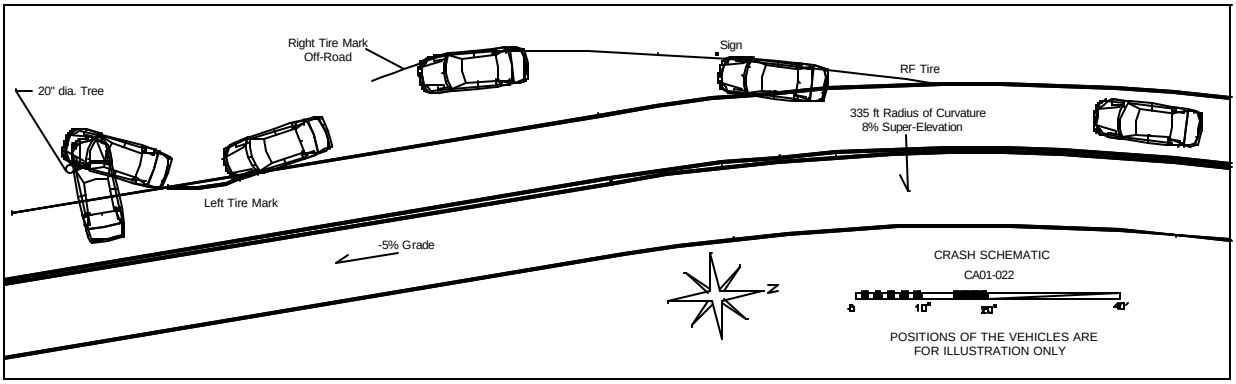


Figure 2 Crash scene schematic.

Post-crash

The police and EMS services responded to the scene. The driver of the Ford was alert and oriented upon the arrival of the first responders. She was seated in an upright posture and restrained by the vehicle's 3-point belt system. Her Glasgow Coma Score (GCS) was 15. There was significant intrusion of the toe pan and left instrument panel into the driver's occupant space. The driver was extricated from the vehicle.

The extrication consisted of the removal of the roof and the front doors and a roll-up of the instrument panel. The extrication took approximately 11 minutes. The restrained driver was effectively protected by the combined protection of the manual 3-point lap and shoulder restraint, driver air bag and left side impact air bag. She sustained bilateral femur fractures, a right patella fracture and minor contusions and lacerations as a result of the crash. She had no injury to her upper torso or head. She was transported and admitted to a regional trauma center post-crash.

2000 FORD TAURUS

The 2000 Ford Taurus, **Figure 3**, was identified by the Vehicle Identification Number (VIN): 1FAFP56S5YA (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 anti-lock brakes. The leather trimmed interior was equipped with a power package that included power steering, brakes, windows, door locks, mirrors and a power driver seat. The driver's foot controls were adjustable. The subject vehicle was also equipped with frontal and side impact air bags for the driver and front right passenger. The 4-door sedan was manufactured in March 2000. The odometer read 18,861 km (11,720 miles) at the time of the inspection.

Figure 3: Front view of the Ford Taurus.

Exterior Damage

Figure 4 is a left front overhead view of the damaged Ford Taurus. The left side of the vehicle impacted the tree approximately on the left front axle with an 11 o'clock direction of force. The direct contact damage began 22.1 cm (8.7 in) forward of the left front axle and extended longitudinally rearward 51 cm (20 in). The combined length of the direct and induced damage measured 130.3 cm (51.3 in). The measured crush profile of the lateral deformation was as follows: C1=0, C2=27.9 cm (11.0 in), C3=35.6 cm (14.0 in), C4=30.5 cm (12.0 in),C5=20.3 cm (8.0 in), C6=0. The vehicle's lateral end shift measured approximately 25 cm (10 in). The left wheelbase was foreshortened 18 cm (7 in) and the force of the impact separated the wheel from the drive shaft. The left lower sill was buckled to a location that measured 167.9 cm (66.1 in) forward of the left rear axle. The Barrier Algorithm of the WINSMASH model calculated a total damage based delta V of 37.0 km/h (23.0 mph). The

Figure 4: Taurus left front overhead view.

longitudinal and lateral components were -32.1 km/h (-19.9 mph) and 18.5 km/h (11.5 mph), respectively. The delta V calculated by the WINSMASH model appeared reasonable. The Collision Deformation Classification was 91-LYEW-3. (Note, the principle direction of force (PDOF) was incremented by 80 to accommodate the left lateral end shift.)

The left front door was buckled and jammed shut by the force of the impact. It was subsequently removed during driver extrication. The extrication process also required the removal of the roof, the right front door and the right rear door. The instrument panel was also rolled-up to free the driver's lower extremities.

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. The driver and front right passenger air bags were designed to deploy at different thresholds of crash severity dependent on restraint use and driver seat position. Side impact air bags designed for head and thorax protection were mounted in the front seat backs. 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 data retrieved from the RCM and subsequently analyzed by Ford was unreliable. The RCM did record the positive status (engaged) of the driver's restraint, however, this condition would have been evoked pre-crash at the vehicle's start-up. The crash event data recorded upon impact was not valid. The RCM did not recognize the deployment of any of the vehicle's safety systems (i.e. pretensioner and/or air bags) and the acceleration data was corrupt. The acceleration data spiked at over 80g's very early in the crash sequence (10-12 milliseconds after initiation) and was not recorded after that time. The RCM was mounted on the center tunnel to the floor pan. The deformation and buckling of the floor pan may have played a role in the loss of the data.

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 had been cut by the first responders. The cut section of webbing measured 102 cm (40 in). The balance of the webbing had spooled back into the retractor and was inaccessible. The left front D-ring was adjusted to its lowest position. At the time of the inspection, the latch plate was still inserted in the buckle. Examination of the latch plate revealed evidence of use

historical. However, there was no evidence on the hard surfaces of the latch plate or D-ring indicative of use during the crash. The driver's buckle pre-tensioner had fired. The post-crash measurement of the pre-tensioner's piston barrel was 75 mm (2.9 in). The pre-crash specification of the barrel length measured 110 mm (4.3 in), therefore the fired pre-tensioner removed 35 mm (1.4 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.

The driver's interior space, **Figure 5**, sustained significant lateral and longitudinal intrusions consistent with the exterior force of the crash. The longitudinal and lateral intrusion of the A-pillar measured 15 cm (6 in) and 10 cm (4 in), respectively. The intrusion of the driver's knee bolster measured 21.6 cm (8.5 in) longitudinally and 10 cm (4 in) laterally. The bolster intrusion was measured at its outboard aspect. The toe pan intrusion documented at the left foot rest location measured 19.1 cm (7.5 in) longitudinally and 27.9 cm (11.0 in) laterally. The 4 o'clock sector of the steering wheel rim contacted the brow of the instrument panel during the impact sequence, as denoted by the contact tape in Figure 5.

Figure 5: Interior intrusion.

The power driver seat was located in a mid track position that measured 9.1 cm (3.6 in) forward of full rear. The seat was located in its at-crash position. The horizontal distance between the center of the steering wheel rim and the seat back measured 49.5 cm (19.5 in). The 4-spoke adjustable steering wheel rim appeared to be adjusted to a center position. There was no rim deformation. The steering wheel was turned approximately 120 degrees counterclockwise. Visual examination of the column indicated it was rotated to a more vertical position probably due to the extrication process. Inspection of the steering column shear capsules determined there was 3.8 cm (1.5 in) of left shear capsule separation. There was no right shear capsule separation. The bend bracket supporting the mid-aspect of the steering column was deformed and the shear coupling on the lower aspect of the column was intact. The adjustable foot controls were positioned 3.2 cm (1.25 in) forward of the most rearward adjustment (with respect to the front of the vehicle).

The driver's knee bolster exhibited a 1.3 cm (0.5 in) scuff as a result of contact with the driver's right lower extremity. The scuff was located approximately 14.0 cm (5.5 in) right of the steering column center line. The left lower extremity pocketed into and contacted the outboard aspect of the mid instrument panel and forward aspect of the left door. Contact to these surfaces in combination with the intrusion resulted in the bilateral femur fractures and right patella fracture.

The driver air bag module was designed in the typical manner and located in the center of the steering wheel. The driver air bag 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). 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 of the back side of the bag. There was no evidence of occupant contact to the air bag. The following nomenclature identified the air bag: P5206000-00D TXM000781426

Figure 6: Left side impact air bag.

The left side impact air bag, **Figure 6**, had deployed from the driver's seat back as a result of the impact. The side bag was designed to offer head and thorax protection. The bag deployed from a 41 cm (16 in) tear of the outboard seam of the seat back. In its deflated state, the lower edge of the bag extended longitudinally forward approximately 36 cm (14 in) from the seat back. This edge was located approximately 20 cm (8 in) above the seat cushion. The vertical dimension of the bag measured 46 cm (18 in). The top of the bag tapered to a width of approximately 23 cm (9 in). The bag was tethered by a single 8 cm (3 in) wide strap. The length of the tether measured 11.4 cm (4.5 in), approximating the inflated dimension of the bag. A 6.4 cm (2.5 in) diameter scuff to the air bag was identified and attributed to contact from the driver's left shoulder. The scuff was centered 6.4 cm (2.5 in) rear of the forward edge of the bag and 41 cm (16 in) above the lower edge. The location of the contact was consistent with the stature of the driver.

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. Inspection of the passenger air bag was unremarkable.

DRIVER DEMOGRAPHICS

Age/Sex:	48 year old/Female
Height:	163 cm (64 in)
Weight:	71 kg (156) lb
Eyewear:	Prescription glasses
Restraint Use:	Restrained by 3-point lap and shoulder belt
Usage Source:	Observation of first responders, SCI inspection, RCM
Medical treatment:	Transported and admitted to a regional trauma center

DRIVER INJURY

Injury	Severity (AIS 98 update)	Injury Mechanism
Left femoral shaft fracture	Serious (851814.3,2)	Intruding knee bolster
Left femoral condyle fracture	Serious (851804.3,2)	Intruding knee bolster
Right femoral shaft fracture	Serious (851814.3,1)	Intruding knee bolster
Right patella fracture	Moderate (852400.2,1)	Intruding knee bolster
Multiple right lower extremity lacerations	Minor (890602.1,1)	Intruding knee bolster
Multiple lower extremity contusions, bilaterally	Minor (890402.1,3)	Intruding knee bolster and door
Multiple left upper extremity contusions (upper arm, elbow, hand)	Minor (790402.1,2)	Inertial loading of the intruding door
Facial contusion	Minor (290402.1,1)	Glasses

DRIVER KINEMATICS

Immediately prior to the crash, the restrained driver was seated in a presumed upright posture with her seat adjusted to a mid-track position. Given the driver's shorter stature, she apparently positioned her seat and the adjustable pedals rearward to maximize her distance from the steering wheel and driver air bag. As such, she was taking full advantage of the features designed into the Ford's advanced occupant protection system.

At impact, the Restraint Control Module (RCM) activated the vehicle's safety systems. The driver seat belt buckle pretensioner fired, removing the slack from the belt system. The frontal air bags and left side impact air bag deployed in response to the force of the 11 o'clock direction of the impact. The driver initiated a forward and left trajectory and loaded the locked seat belt. Her head, shoulder and left flank loaded the deployed left side impact air bag backed by the intruding left door. Multiple left side contusions resulted from this contact. The intrusion of the left A-pillar and instrument panel, into the driver's space, brought the knee bolster into contact with the driver's lower extremities. The bilateral femur and right patella fractures and minor lower extremity lacerations resulted from this contact. She probably contacted

the center and outboard aspect of the driver air bag. This contact did not produce any injury. The driver then rebounded into the seat where she was found. The driver suffered no upper thoracic or head injury. The proper use of the manual 3-point restraint and deployment of the vehicle's safety systems effectively mitigated this driver's injuries.

ATTACHMENT A

2000 Taurus/Sable EDR Report - Summary Page

Investigation Data

File Name:	Ca01-022.hex	File Save Date:	16-Feb-2001
File Read-out Date:	N/A	Report Date:	16-Feb-2001
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:	0
Time From Algorithm Wakeup to First Stage - Unbelted:	0
Time From Algorithm Wakeup to First Stage - Belted:	0
Time From Algorithm Wakeup to Second Stage:	0

Restraint System Status

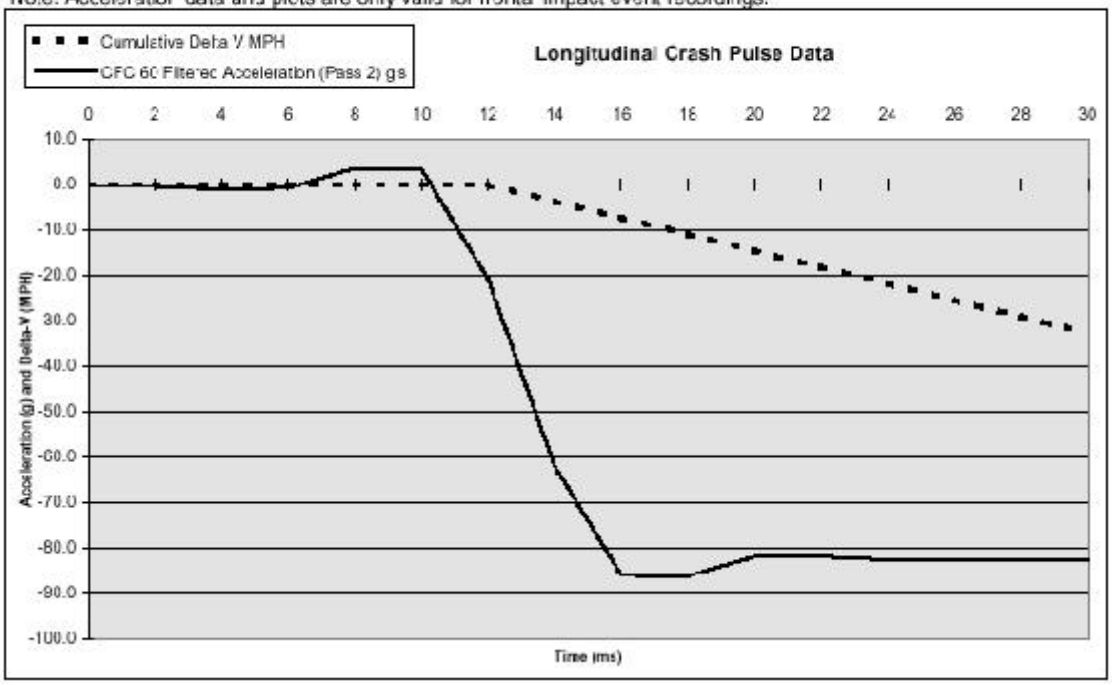
Driver Seat Belt Buckle:	Engaged
Passenger Seat Belt Buckle:	Not Engaged
Driver Seat Track In Forward Position:	No
Passenger Seat Weight Switch Position:	N/A

Deployment Initiation Attempt Times	Driver	Passenger
Time From Algorithm Wakeup to Pretensioner Deployment Attempt:	Not Deployed	Not Deployed
Time From Algorithm Wakeup to First Stage Deployment Attempt:	Not Deployed	Not Deployed
Time From Algorithm Wakeup to Second Stage Deployment Attempt:	Not Deployed	Not Deployed

Longitudinal Cumulative Delta-V

Time (ms)	0	10	20	30	40	50	60	70	78
Delta-V (MPH)	0.0	-0.1	-14.6	-32.7	No Data	No Data	No Data	No Data	No Data

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)	-0.1	0.0	-11.6	-24.7	No Data	No Data	No Data	No Data	No Data

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