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ADVANCED OCCUPANT PROTECTION SYSTEM STUDY
2000 FORD TAURUS INVESTIGATION

VERIDIAN CASE NO. CA01-020

LOCATION - PENNSYLVANIA

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 seat position (driver only . The vehicle was also equipped with side impact air bags for the front occupants. The subject 2000 Ford Taurus was involved in an intersection crash with a 1989 Jeep Comanche. The 48 year old male driver and 47 year old female front right passenger were both restrained by the vehicle's 3-point lap and shoulder belt at the time of the crash. The force of the crash caused the front seat belt pretensioners to fire but was below the threshold required to deploy the frontal air bags. The female passenger sustained a right trapezius strain (i.e. neck and shoulder) , as a result of the crash. She was treated and released from a local hospital the day of the crash. The driver complained of a left shoulder contusion and refused medical attention.

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ADVANCED OCCUPANT PROTECTION SYSTEM STUDY
2000 FORD TAURUS
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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 vehicle was also equipped with side impact air bags for the front occupants. The subject 2000 Ford Taurus was involved in an intersection crash with a 1989 Jeep Comanche. The 48 year old male driver and 47 year old female front right passenger were both restrained by the vehicle's 3-point lap and shoulder belt at the time of the crash. The force of the crash caused the front seat belt pretensioners to fire but was below the threshold required to deploy the frontal air bags. The female passenger sustained a right trapezius strain (i.e. neck and shoulder strain), as a result of the crash. She was treated and released from a local hospital the day of the crash. The driver complained of a left shoulder contusion and refused medical attention.

The Crash Investigations Division of the National Highway Traffic Safety Administration (NHTSA) was informed of the crash on January 31, 2001 by the driver of the Ford. 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.

SUMMARY

Crash Site

This two-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 three lanes, a single lane for the north and south travel direction and a center turn-only lane. The road was straight with a negative grade (estimated less than 2 percent) to the south. A secondary road intersected from the west, forming a three-leg intersection at the crash site. The speed limit in the area of the crash was 64 km/h (40 mph). **Figure 1** is a southbound trajectory of the Ford Taurus.

Figure 1: Trajectory view of the Ford Taurus.

Pre-crash

The 2000 Ford Taurus was southbound driven by a 48 year old restrained male. A 47 year old restrained female was the front right occupant. Coincident to the Ford's approach, a 1989 Jeep Comanche was northbound driven by a 36 year old male. The Jeep was in the center turn lane. Immediately prior to the crash, the Jeep turned left across the path of the Ford. It was the intention of the Jeep's driver to travel west on the intersecting side street. The driver of the Ford Taurus indicated he was traveling approximately 64 to 72 km/h (40 to 45 mph) in a line of 3 to 4 other vehicles. The driver recognized the impending crash and reacted by steering clockwise (right) and locking the vehicle's brakes in an avoidance maneuver. The Ford Taurus was equipped with an anti-lock braking system. No tire marks were identified by the police investigation.

Crash

The crash occurred with the front of the Taurus impacting the front aspect of the Jeep's right side in an 11/2 o'clock impact configuration. **Figure 2** is a schematic of the crash. The force of the crash, forward of its center of gravity, caused the Jeep to begin to rotate counterclockwise. The pre-crash steering of the Taurus coupled with the lateral momentum of the Jeep caused the Taurus to rotate clockwise. As the respective vehicles rotated away from the initial impact, the right rear of the Jeep contacted the left side of the Taurus in a secondary side slap. The Jeep then slid to rest in the southwest quadrant of the intersection facing westward. The Taurus came to rest in the mouth of the intersection facing west. The total delta V of the Ford's front impact calculated by a WINSMASH analysis was 13.3 km/h (8.3 mph). The longitudinal and lateral components were -11.5 km/h (-7.2 mph) and 6.7 km/h (4.2 mph), respectively.

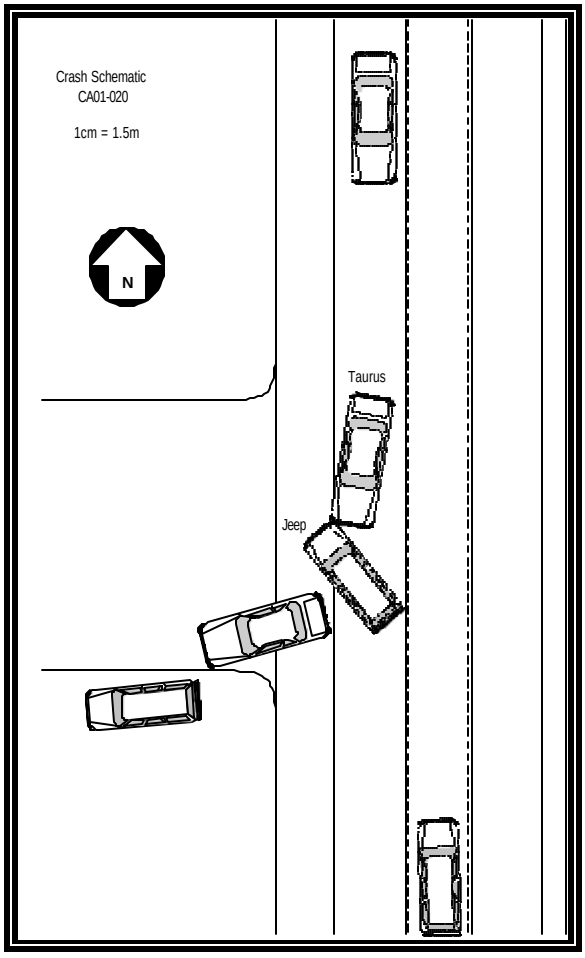


Figure 2: Crash schematic.

Post-crash

The police and EMS services responded to the scene. The driver of the Ford exited the vehicle from the left front door. He reportedly sustained a left shoulder contusion as a result of seat belt loading and was otherwise uninjured. The front right passenger tried to exit the vehicle but found the right front door restricted . She climbed over the center console and exited the vehicle from the left and sat down to the rear left seat. She remained seated in the vehicle until the arrival of the ambulance. She complained of soreness to her right arm and neck. She was transported to a local hospital, examined and released the same day. The driver of the Jeep Comanche was not injured in the event.

2000 FORD TAURUS

The 2000 Ford Taurus, **Figure 3**, was identified by the Vehicle Identification Number (VIN): 1FAFP55U2YA (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 was equipped with 4-wheel disc anti-lock brakes. The cloth 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 not adjustable. The subject vehicle was equipped with frontal air bags for the driver and front right passenger. The 4-door sedan was manufactured in June 2000. The odometer read 35,350 km (21,966 miles) at the time of the inspection. The vehicle was owned by a rental agency and was being operated under a rental agreement at the time of the crash.

Figure 3: Front view of the Ford Taurus.

Primary Exterior Damage

Figure 4 is a left lateral view of the frontal deformation. The front bumper sustained 118.1 cm (46.5 in) of direct contact damage. The direct contact began 63.5 cm (25.0 in) left of center and ended 54.6 cm (21.5 in) right of center. The structure of the front bumper was shifted 5.8 cm (2.3 in) to the right as a result of the force of the 11 o'clock impact. The energy of the crash was managed primarily by the vehicle's bumper and structures forward of the cowl. The measured crush profile was as follows: C1=10.9 cm (4.3 in), C2=7.9 cm (3.1 in), C3=7.6 cm (3.1 in), C4=5.1 cm (2.0 in),C5=6.6 cm (2.6 in), C6=10.2 cm (4.0 in). The imprint of the Jeep's right front rim was identified on the bumper fascia. The center of the imprint was located 35.6 cm (14.0 in) right of center. The right front door was restricted by the deformation of the right front fender. The right rear door was jammed shut. There was no change on the wheelbase dimensions. The Damage Algorithm of the WINSMASH model calculated a total delta V of 13.3 km/h (8.3 mph) for the Taurus. The longitudinal and lateral components were -11.5 km/h (-7.2 mph) and 6.7 km/h (4.2 mph), respectively. The calculated delta V seemed underestimated based on SCI field experience. A more probable delta V for the Taurus was in the range of 16 to 19 km/h (10 to 12 mph). The Collision Deformation Classification (CDC) was 11-FDEW-1.

Figure 4: Left lateral view across the front plane.

Secondary Exterior Damage

The side slap damage along the Taurus's left side consisted of minor abrasion and buckling of the left front fender and the forward aspect of the left front door. There was no measurable deformation. The direct contact began 13 cm (5 in) rearward of the left front axle and measured approximately 43 cm (17 in) in length. The damage ended 56 cm (22 in) rearward of the left front axle, on the forward aspect of the left front door. The left outside mirror was displaced from its mount during the secondary impact. The CDC was this impact was 09-LYEW-1.

1989 JEEP COMANCHE

The 1989 Jeep Comanche, **Figure 5**, was identified by the Vehicle Identification Number (VIN): 1J7FT36L1KL (production sequence deleted). The 4x2 Pioneer model pick-up truck was configured with a 287 cm (113 in) wheelbase. The power train consisted of a 2.5 liter, I-4 engine linked to a 4-speed manual transmission. The service brake system was front disc/rear drum. The restraint system consisted of manual 3-point lap and shoulder belts for the driver and front passenger.

Figure 5: Jeep Comanche right side damage.

Primary Exterior Damage

The vehicle's right side damage began at the right front bumper corner and extended 213 cm (84 in) rearward to the location of the B-pillar. The maximum deformation was approximately centered on the right door and measured 13 cm (5 in). The right door was jammed shut by the deformation and the glazing disintegrated on impact. The force of the impact displaced the right front wheel from the axle. The total delta V calculated by the Damage Algorithm of the WINSMASH model was 15.7 km/h (9.8 mph). The CDC was 02-RYEW-3.

Secondary Exterior Damage

The right side slap damage was confined to the vehicle's right rear quarterpanel behind the rear axle and consisted of abrasion to the body panels. The damage began approximately 25 cm (10 in) rearward of the right rear axle and extended 74 cm (29 in) to the bumper corner. The CDC of this contact was 03-RBEW-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. 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 RCM data indicated the front belt systems were buckled at the time of the crash and the buckle pre-tensioners fired 42 milliseconds after algorithm initiation. The driver seat was not adjusted to a forward position and the frontal air bags were not commanded to deploy. 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 -17.5 km/h (-10.9 mph). The 78 millisecond lateral delta V was approximately 10.0 km/h (6.2 mph). Analysis of the acceleration pulse and velocity curves indicated that only a portion of this long duration crash event was recorded. The acceleration traces were still active and the velocity curves were still rising at the termination of 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. Historical usage evidence was identified on the latch plate, however, this evidence was not indicative of the driver's habits as the vehicle was a rental. In an interview, the driver indicated he was a habitual belt user, as was the front right passenger (his wife). 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, **Figure 6**. The post-crash measurement of the pre-tensioner's piston barrel was 66 mm (2.6 in). The pre-crash specification of the barrel length measured 110 mm (4.3 in), therefore the fired pre-tensioner removed 44 mm (1.7 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.

Figure 6: View of the fired pre-tensioners.

The front right restraint webbing was stowed and operational at inspection. The webbing and latch plate exhibited historical evidence similar in nature to the driver's restraint. The adjustable right upper

anchorage (D-ring) was positioned 2.5 cm (1.0 in) below full up. There was no evidence of loading to the restraint webbing or hardware. The right buckle pre-tensioner had fired, Figure 6. The piston barrel measured 71 mm (2.8 in). This measurement indicated approximately 39 mm (1.5 in) of slack was removed by the fired pre-tensioner. All the evidence identified during the inspection indicated the front right passenger was restrained during the crash.

Figure 7 is a view of the front occupant space of the subject vehicle. There was no intrusion or interior damage associated to the forces of the crash. No points of occupant contact could be identified. The absence of interior occupant contacts was directly related to the proper use of the vehicle's manual 3-point restraint.

Figure 7: View of the front interior.

The driver seat was adjusted to the full rear position. The right front seat was adjusted in a rear-track position and measured approximately 8 cm (3 in) forward of full rear. These at-crash track positions were confirmed by an interview with the driver.

The 4-spoke adjustable steering wheel rim was adjusted to a center position. There was no rim deformation. The steering wheel was turned approximately 120 degrees counterclockwise. 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 not damaged and intact.

The driver air bag module was designed in the typical manner and located in the center of the steering wheel. The front right passenger air bag module was a top mount design located in the right aspect of the instrument panel. The frontal air bags were not deployed. The crash severity was below the threshold required for air bag deployment, considering both front occupants were restrained.

OCCUPANT DEMOGRAPHICS

	Driver	Front right passenger
Age/Sex:	48 year old/Male	47 year old/Female
Height:	183 cm (72 in)	157 cm (62 in)
Weight:	125 kg (275 lb)	68 kg (150 lb)
Restraint Use:	3-point lap and shoulder	3-point lap and shoulder
Usage Source:	SCI inspection, RCM	SCI inspection, RCM
Medical Treatment:	None	Treated and released

DRIVER INJURY

Injury	Severity (AIS 98 update)	Injury Mechanism
Left shoulder contusion	Minor (790402.1,2)	Inertial contact with 3-point restraint

Note: the above injury was identified through an interview with the driver

DRIVER KINEMATICS

Immediately prior to the crash, the restrained driver was seated in an upright posture with his seat adjusted to a rear track position. The driver was bracing for the impact with his arms and had his feet firmly on the brake. At impact, the buckle pretensioner fired and removed the slack from the belt system. The driver responded to the 11 o'clock direction of the impact by initiating a forward trajectory and loading the restraint system. The inertial loading of the restraint resulted in the left shoulder contusion. As the vehicles contacted in the secondary side slap, the driver moved to the left in response to the 9 o'clock direction of impact. The driver believed he contacted the interior door panel as a result. This contact did not result in an injury. The proper use of the 3-point restraint maintained the driver in an upright position and mitigated his contact with the forward structures of the vehicle's interior. The restraint system effectively protected the driver in this minor severity crash.

FRONT RIGHT PASSENGER INJURY

Injury	Severity (AIS 98 update)	Injury Mechanism
Right trapezius strain	Minor (740402.1,1)	Inertial motion associated with restraint use

Note: the above injury was identified in the Emergency Room Report for the passenger. The record suggested the possibility this injury may have been pre-existing and further aggravated by this crash.

FRONT RIGHT PASSENGER KINEMATICS

Immediately prior to the crash, the restrained front right passenger was seated in an upright posture with her seat adjusted in a rear track position. The passenger reportedly extended her right arm forward in an attempt to brace for the impending crash. At impact, the buckle pretensioner fired and removed the slack from the belt system. The passenger responded to the 11 o'clock direction of the impact by exhibiting a forward trajectory and loading the restraint system. As the passenger's upper torso rode down the crash, the inertia of the head continued forward and the neck flexed down in an arcing pattern. The musculature of the shoulders and neck resisted the forward inertia of the head. The trapezius strain resulted from this kinematic pattern. As the vehicle's impacted in the secondary side slap, the passenger responded to the 9 o'clock direction of the impact by moving to the left. Passenger contact to the forward interior structure of the vehicle was minimized by the proper use of the vehicle's 3-point restraint system and prevented the passenger from sustaining more significant injury.

ATTACHMENT A

Investigation Data

File Name:	Ca01-020.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:	42
Time From Algorithm Wakeup to First Stage - Unbelted:	42
Time From Algorithm Wakeup to First Stage - Belted:	0
Time From Algorithm Wakeup to Second Stage:	0

Restraint System Status

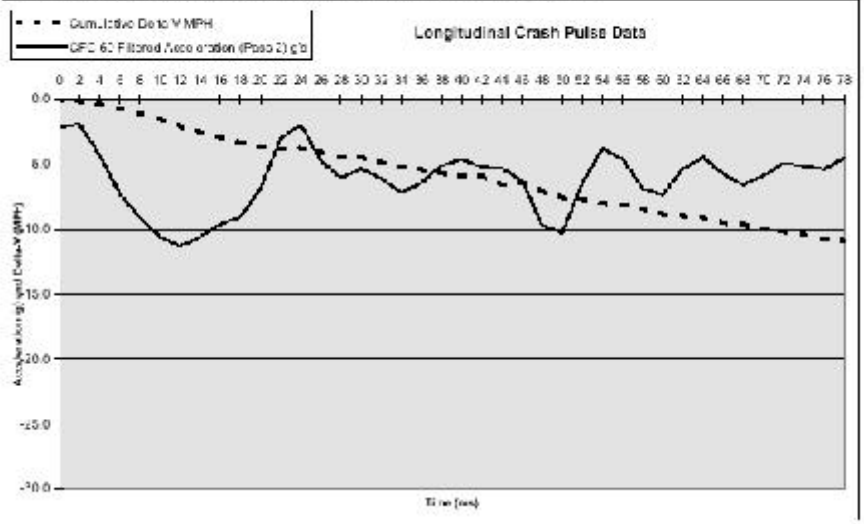
Driver Seat Belt Buckle:	Engaged
Passenger Seat Belt Buckle:	Engaged
Driver Seat Track In Forward Position:	No
Passenger Seat Weight Switch Position:	N/A

Deployment Initiation Attempt Times	Driver	Passenger
Time From Algorithm Wakeup to Pretensioner Deployment Attempt:	42	42
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)	-0.2	-1.6	-4.7	-6.5	-5.9	-2.6	-0.8	-10.1	-10.2

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)	0.0	0.5	1.3	3.3	3.3	3.0	4.0	5.1	6.2

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