Safety Standard's Failure to Reveal Defects In Police Vehicle's Fuel System Crashworthiness

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Abstract - United States Department of Transportation (USDOT) Federal Motor Vehicle Safety Standard 301 (FMVSS301) dictates motor vehicle fuel system integrity minimum performance. Ford Motor Company's (Ford) Crown Victoria Police Interceptor (CVPI), the most popular police car in the United States, meets the performance criteria of FMVSS301 and appears to meet the proposed updated rear impact test requirements. Ford's CVPI also passed the criteria dictated by the USDOT New Car Assessment Program (NCAP), a program that tests vehicles at speeds higher than the FMVSS. The CVPI performance in standard testing and assessments is contrasted to the CVPI's real world performance in which a series of highly publicized crashes resulted in punctures of the fuel tank and burn injuries and burn deaths and to police officers. Evaluations of real world crashes reveal vehicle defects that are addressed in part by Ford through a variety of remedial design related mechanism including service bulletins, retrofits, design changes and accessory safety equipment. High-speed 50% offset 75 mph car-to-car crash tests, test and analysis at crash severity well in excess of government safety standards, are conducted to validate and evaluate potential remedies of the vehicle's defects. The method and analysis employed to identify problems with the CVPI fuel containment system is presented. The results of testing used in the identification of fuel tank problems, evaluation of equipment and validation of remedial fuel system improvements is presented. Standardized testing used in assessing fuel system performance of the Ford CVPI police car is identified as an incomplete indicator of the fuel system's actual crash performance.

INTRODUCTION

The vehicles described in this manuscript include the 1992 to present Ford Crown Victoria Police Interceptor (CVPI). The vehicle, although represented to be specifically designed, engineered and equipped for police use, is identical to the civilian-use Ford Crown Victoria except for minor upgrades to the vehicle handling, larger engine and installed police equipment. The fuel containment system, in this particular design, orientates the fuel tank vertically, located immediately to the rear of the rear axle and suspension, and immediately forward of a deep well trunk as illustrated in Figure 1.

Ford introduced the vertical behind-the-axle fuel tank design in the 1965 Ford Galaxie. This basic vertical behind-the-axle fuel tank design was used from 1965 through 1978 in full size Ford, Mercury and Lincoln automobiles. The full size automobiles received a new design for the 1979 model year, but the new 1979 design continued to use the vertical behind-the-axle fuel tank in which the fuel tank remained located immediately to the rear of the axle and forward of the deep well trunk. The 1979

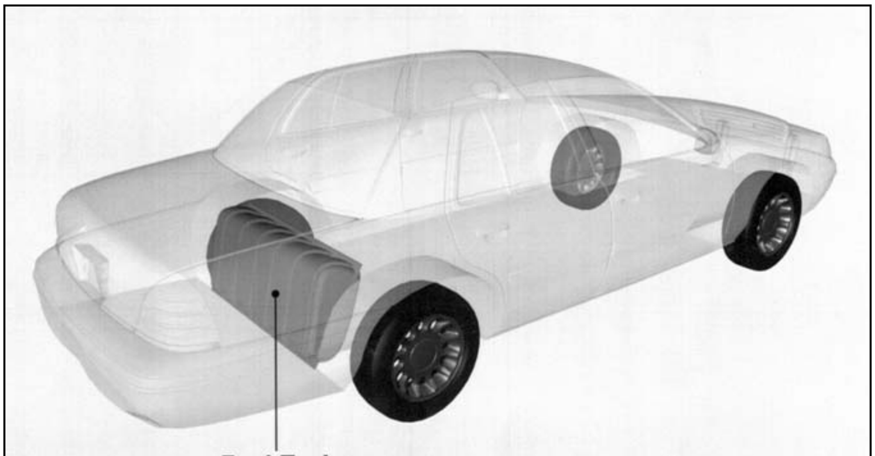

Figure 1, CVPI Vertical-Behind-The-Axle Fuel Tank design was known as the Panther platform, which includes the full-size Ford Crown Victoria, Mercury Grand Marquis, and Lincoln Town Car. The Panther platform has continued in production until the present, using the same basic vehicle architecture, including the vertical behind-the-axle fuel tank. An update and refreshing of the Panther platform occurred in 1992 and while upgrades and changes in the detail have occurred in the as-sold fuel containment system the basic system crash performance is the same.

Police vehicles are used in unique ways that greatly increases their exposure to high speed accidents. Ford Motor Company reported [1] that police vehicles are driven 10 times more hours per day and four times more miles per year than civilian vehicles, police vehicles are used more often during high-risk night time hours, and police vehicles stop along highways at least 1,000 times more per year compared to non-police vehicles. The United States Department of Transportation (USDOT) Nation Highway Transportation safety Administration (NHTSA) noted [2] that police-use configured vehicles distinguished from their civilian counterparts have a much greater exposure to high-energy rear impacts due to the nature of their use as blocker vehicles at crash scenes or during routine traffic stops along high-speed public roads. Police vehicle rear impact collisions involving post-crash fuel tank failure and fuel leakage or fire are described [2,3] to involve forces, or energy, placed upon the vehicle well in excess of applicable (US) Federal Motor Vehicle Safety Standards (FMVSS).

Ford has manufactured vehicles used by police for over 70 years and was describe in 1997 as [4], "with no real competition." NHTSA at the closure of its Service Query in October of 2002 wrote [5] that the CVPI is the overwhelming vehicle of choice for police duty and that the only other comparable vehicle was the Chevrolet Caprice which stopped production after model year 1996. In May of 2003 Ford stated its CVPI had an 85% market share [6].

Motor vehicle crashworthiness related to post crash fires as a cause of injury and death is guided by the design principal [7] that an ideal crash resistant fuel system will completely contain its contents both during and after an accident of such severity as to be beyond the boundary of any conceivable survivable accident for the vehicle under consideration. Based largely upon the study of aircraft crashes this principal was published in 1966, however was restated in 1974 after a study of automotive collision fires. The 1974 study stated [8], allow no fuel leakage for those collisions in which occupants can survive the trauma, further stating, fuel system integrity warrants special and continuous scrutiny with the goal of eliminating post crash fires in all accidents except where the vehicle is totally devastated. Of course, the USDOT standard in place up through today is far below that suggested by decades old state-of-the-art technical literature. Presently, and since 1977, all vehicles legal for sale in the United States must pass FMVSS 301 which requires an impact at the rear by a 1814 kg non-deforming moving barrier at 48 kph, impact at the side by a 1814 kg non-deforming moving barrier at 32 kph and impact at the front into a fixed non-deforming barrier at 48 kph. An update to FMVSS 301 will phase into effect from model year 2007 through 2009 and will require a rear impact by a 1368 kg deforming barrier, offset with a 70% overlap at 80 kph and an impact at either side by a 1368 kg deforming moving barrier at 53 kph. There is no update of the frontal impact requirements.

METHOD

Beginning in 1999 and continuing until the present a crash database containing research and investigation of post-rear-impact collision fuel leakage or fuel fed fires in Ford Panther platform including Ford CVPI automobiles was developed. Most of the crashes in the database involve a fire, but leakage only incidents are included for identification and refinement of failure modes. Leakage only incidents are also included since the prevention of fuel leakage is recognized as the best way to prevent post crash burns [8]. For each crash a reconstruction code dictated by the protocol of SAE Collision Damage Classifications (CDC) [9] is determined. In addition, details regarding the performance and failure mode of the fuel containment system are documented pursuant to a series of fuel system failure codes. Coding that identifies specific failures is dictated by a written Fuel System

Failure Classification (FFC) protocol shown in the Appendix, Table A1. Failure counts for each classification code are also included in the Appendix, Figure A1. Analysis identifies crashes manifesting fuel containment system failure by known defects. Dominant failure causing mechanisms are addressed by remedial treatments through Technical Service Bulletins (TSB), retrofits, offerings for sale of auxiliary components and improved instruction and warning. Real world crashes are contrasted to crash tests conducted at a range of impact severity. A standardized car to car crash test at 50% offset and nominal impact speed of 120 kph with police equipment placed as cargo in the trunk emerges as a standardized test for evaluating police vehicle fuel system performance. Analysis attempts to verify the effectiveness of various remedial treatments.

RESULTS, CRASH DATABASE

The February 2004 update of the database is presented. In the course of analysis, 60 crashes of Ford Panther platform vehicles, including the CVPI, are identified in which the vehicle was impacted at the rear. The population of 60 crashes will be referred to as Back Damage Crashes (BDC). Forty-five of the BDC are confirmed to leak fuel from breaches in the fuel containment system as a result of the collision. The population of 45 crashes will be referred to as Other Similar Incidents (OSI). Within the population of BDC and OSI 45 and 38 are CVPI, respectively.

Collision Damage Classification (CDC)

Coding of the CDC for each crash provides the basis for the filter that identifies the BDC population. Specifically, crashes that have a five, six and seven o'clock principal direction of force (PDOF) and a (B)ack damage code are included in the BDC. Back Damage Crashes include 1 at 5 o'clock, 58 at 6 o'clock and 1 at 7 o'clock. OSI crashes include 44 at 6 o'clock and 1 at 7 o'clock. The distribution of back damage lateral location is shown in Table 1. The most common back damage locations are (D)istributed, involving direct contact to all thirds of the rear, (19 BDC and 15 OSI) and (Y) the left two thirds (14 BDC and 13 OSI). The distribution of damage extent is shown in Table 2 and the cumulative frequency of the known damage extent for the two populations is shown in Figure 2.

CDC Lateral Damage Location	Distributed	Right Two-thirds	Left Two-thirds	Right One-third	Center One-third	Left One-third	Unknown
	D	Z	Y	R	C	L	Unk
BDC	19	12	14	1	3	4	7
OSI	15	11	13	0	3	2	1

Table 2, Distribution of CDC Lateral Damage Location

Damage Extent	Unk	1	2	3	4	5	6	7	8	9
OSI	1	0	0	1	2	3	15	13	8	2
BDC	8	0	0	2	2	4	18	14	10	2

Table 1, Distribution of CDC Damage Extent

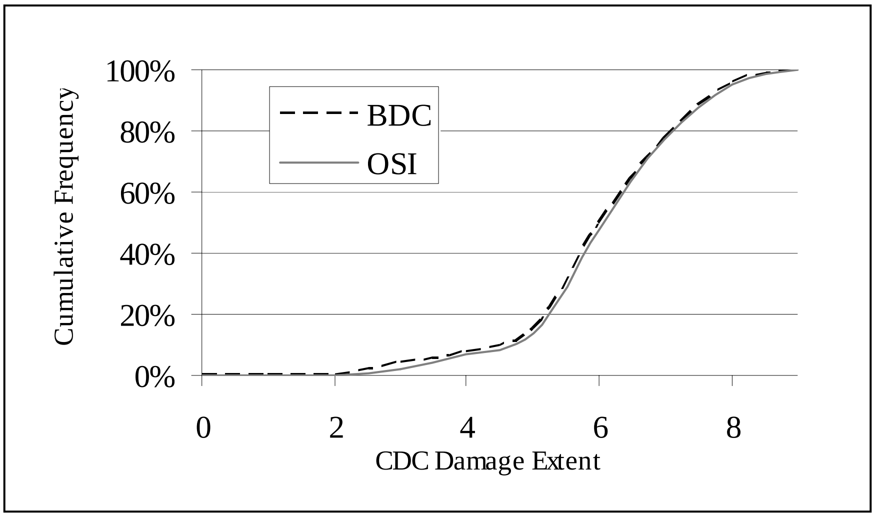

Figure 2, Cumulative Frequency of known CDC Damage Extent

Failure Mode Coding

Failure mode coding requires the confirmation that fuel containment system failure has occurred as a result of the collision, determination of the type of failure mode and finally classification of the specific fuel system failure using the FFC. Confirmation of failure(s) of the fuel containment system as a result of a collision involves an analysis of system performance. Knowledgeable engineering analysis, often in combination with photographs documenting failures, documents describing failures, review of crash circumstances and other available information is the basis for failure mode coding. By definition each crash in the OSI population has an affirmative answer to the question – did the fuel containment system fail as a result of the collision? Lacking an affirmative answer to this question no further failure mode coding is attempted.

There are three types of crash induced fuel containment system failure modes. The three failure modes are applicable to all motor vehicle fuel containment systems and have been identified in prior published research describing defects and crash induced failures of light pickup trucks side mounted saddle fuel tanks [10]. Further, the three crash induced fuel containment system failure modes parallel the containment integrity guidelines outlined in the SAE Surface Vehicle Information Report, “Passenger Car and Light Truck Fuel Containment” [11]. The three failure modes are: (1) crush failures due to the fuel tank location and mounting, (2) puncture failures due to puncture producing objects in the fuel containment systems environment, and (3) filler neck and/or fuel cap failure. One or all of the failure modes may be manifested in any given crash. For the CVPI because the fuel tank is located behind the axle and in front of crash induced intruding structures failure mode 1, crush failures due to the fuel tanks location and mounting is usually manifested. All (45) OSI crashes manifest failure mode 1, while 27 OSI crashes manifest failure mode 2 and eight (8) OSI crashes manifest failure mode 3.

Fuel System Failure Classification (FFC)

The FFC is a detailed classification of all individual crash induced failures of a fuel containment system. It is not uncommon for a single fuel containment system to sustain multiple crash induced failures. For the 45 OSI there are a total of 106 fuel system failures. Each failure is assigned an area. The areas with an accompanying count of failures per area are: 52 (F)ront, 24 (B)ack, 0 (S)eam, 16 (O)ther, 10 filler (N)eck and 4 unknown.

	Left Third	Center Third	Right third
Top	B=0, F=0	B=1, F=0	B=0, F=0
Upper Half	B=2, F=3	B=1, F=3	B=2, F=0
Lower Half	B=5, F=24	B=3, F=6	B=9, F=14
Bottom	B=1, F=0	B=0, F=2	B=0, F=0
Vert Position Unk	B=0, F=0	B=0, F=0	B=0, F=0

Unknown: B=1, F=0

Table 3, (F)ront and (B)ack Fuel Tank Failure Location

Distribution by location of failure for the (F)ront area and (B)ack area of the fuel tank is shown in figure 3. Most failure locations are at the bottom half of the fuel tank because interference between the tank and axle biased to the bottom of the fuel tank and the load path from objects in the trunk of the vehicle is biased lower. Failures to the back of the tank are more distributed and less bias to the bottom half when compared to the distribution of failures to the front of the fuel tank. Failures to the front of the fuel tank are dominated by crash induced deformation and crushing due to tank to axle/differential interaction.

The distribution by assembly/mechanism induced failure for the (F)ront area and (B)ack area of the fuel tank are shown in figure 3. For the (F)ront area it is notable that 44 (84%) failures are caused by the axle/differential assembly. Five distinct components of the axle/differential assembly are classified as causing punctures of the fuel tank. The distinct axle/differential components with an accompanying count of failures per component are: six (6) by the parking brake cable mounting bolt, 13 by the shock absorber mounting bracket, seven (7) by the sway bar mounting bracket, seven (7) by the coil spring seat, lower mount, seven (7) by the differential rear cover and five (4) not specified on the axle/differential assembly. To the (B)ack area most failures are due to trunk equipment, four (4) by mounted trunk equipment, eight (8) by non-mounted trunk equipment, and two (2) by not specified trunk equipment. Seven (7) failures to the (B)ack area are from deforming vehicle components including aspects of the fuel tank strap mount and deforming metal.

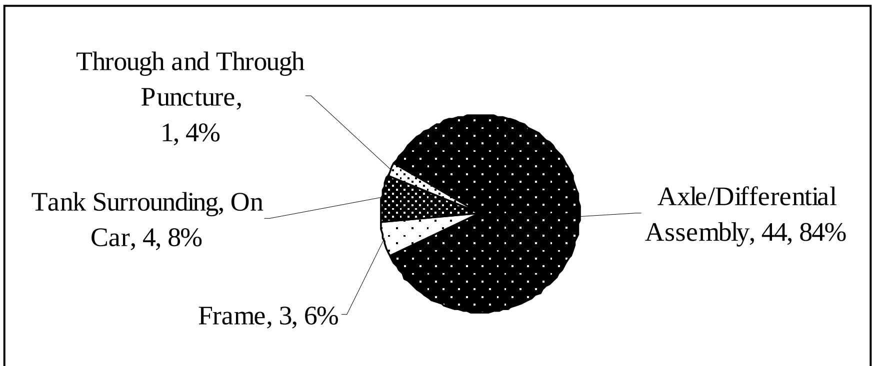

Figure 3, Assembly/Mechanism of (F)ront Failures

The 16 failures to the (O)ther area are six (6) failures of the sender unit mounted to the front center upper half of the tank and 10 failures of the valves and fittings located at the top of the fuel tank. Of the 10 filler (N)eck area failures, five (5) are due to crush and breakage of the grommet seal and five (5) are due to failures in the steel filler neck tube. Failure of the (S)eam is not observed.

RESULTS – CRASH TEST

Numerous controlled rear impact crash test have been conducted on the CVPI including: 48 kph Rear Moving Barrier (RMB) (FMVSS Compliance); 56 kph RMB (NCAP); 80 kph, 50% overlap Taurus-to-car; 80 kph, full overlap Taurus-to-car; 80 mph 70% overlap Deforming (D)RMB (approximated update to FMVSS start effective date MY 2007); 120 kph, 50% overlap Taurus-to-car and 160 kph, 85% overlap Crown Victoria-to-car. Typical post crash rear bumper profiles and CDC damage extent regions are overlaid onto an undamaged vehicle in Figure 4. Because a standardized rear impact test of police vehicles utilized a Ford Taurus sedan impacting at 120 kph with a 50% overlap, a speed versus damage characterization is developed using the 80 kph and 120 kph, 50% overlap tests and the 160 kph test. An equivalent Taurus speed in the 160 mph Crown Victoria-to-car test, assuming constant vehicle properties, is calculated at 175 kph. Damage area and extent are coded for the crash tested vehicles using the CDC protocols. Applying the damage area equivalent speed characterization to the crash populations CVPI OSI and non-CVPI OSI yields the distribution of speeds shown in figure 5. The 50th percentile speed is 97 kph for non-CVPI OSI and is 107 kph for CVPI OSI.

Crash testing used by Ford in the development and presumed validation of the CVPI prior to 2002 included RMB testing at 48 kph and 56 kph and Taurus-to-car testing at 80 kph with complete overlap and 50% overlap. Referencing figure 5, an 80 kph, and 50% overlap test produces a CDC damage extent of five (5), or severity at the 24th percentile, for the population of CVPI OSI crashes in this study. Although some crash test induced incipient failures are observed, most of the failures demonstrated in the investigation of real world crashes did not occur in crash testing.

Crash tests are conducted with the fuel tank filled to 95% of its usable capacity. Police practice involving refilling of fuel tanks probably differ from civilian practice, but actual use of all vehicles will result in fuel volumes on average less than 95% of usable capacity. The amount of crush that a fuel tank sustains is a function of its fuel volume. A fuel tank's volume reduction is limited by its load of incompressible liquid. Initial 110 kph to 120 kph crash tests with the fuel tank 95% at 95% of usable capacity did not result in punctures from objects on the differential/axle assembly in part

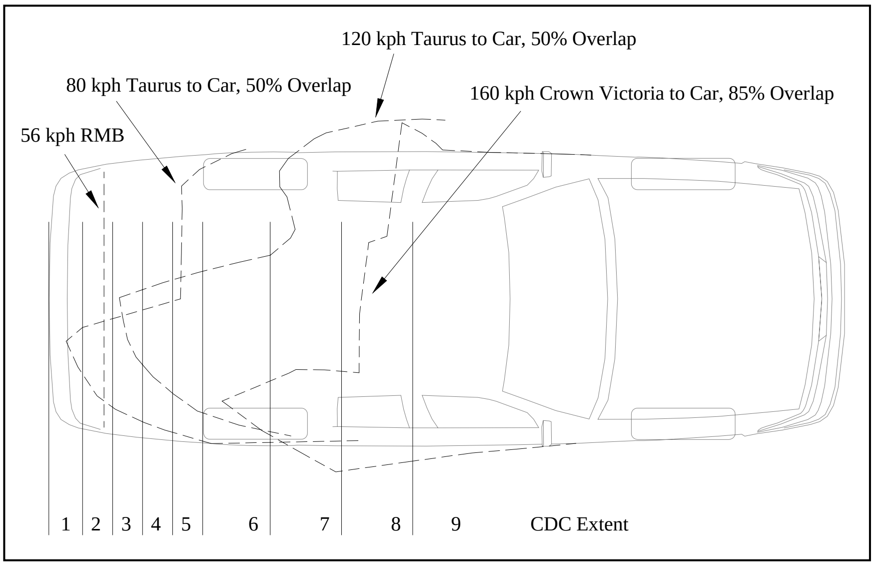

Figure 4, CDC Damage Extent and Typical Crash Test Damage

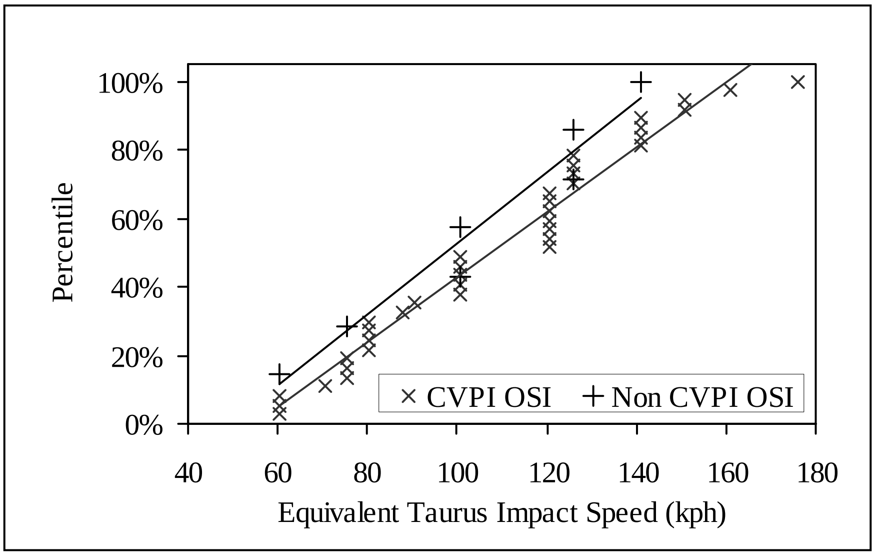

Figure 5, Cumulative Frequency of Equivalent Taurus Speed

because they differed from real crash fuel tank volumes. Measured fuel tank volume reductions in 110 kph to 160 kph crash tests in which the fuel tank fluid volume was initially 95% of usable capacity resulted in volume reductions of 7.6 liters to 14.8 liters. Of eight (8) fuel tanks from the OSI population that were measured the volume reduction was 12.1 liters to 34.8 liters. Most known pre crash fuel volumes from the OSI population are less than 95% of usable capacity.

DISCUSSION

The author's first investigation of a CVPI rear impact post crash fire occurred in summer of 1999 and involved a 1996 CVPI. The cause of fire and resulting fatal burns to the police office was a failure of the fuel tank by puncture from the parking brake cable bracket mounting bolt (FFC = IFA1). The parking brake cable bracket mounting bolt is mounted to the back of the axle/differential assembly and its hex head is directed at the front face lower half of the fuel tank. Apart from crash test results or demonstration in other crashes of the same failure mode, the vehicle design did not reflect established attributes that recognize and eliminate the potential for fuel tank puncture. A detailed failure mode and effect analysis would have identified and eliminated the danger posed by the parking brake cable bracket mounting bolt and other puncturing object located axle/differential assembly. Prior to the summer of 1999 the Florida State Highway Patrol undertook its investigations of the CVPI after several of its officers were fatally burned in CVPI rear impact post crash fires [3]. After the summer of 1999 police office deaths involving identical fuel tank failure modes continued to occur in CVPI.

The crash database described in this study is not a statistically sampled database. The database does represent a population of crashes located through an extensive network of police and police agencies. Heightened awareness of the press, police and police agencies regarding fuel leakage and fires in CVPI following rear impact caused cooperative identification and reporting of crashes. Analysis did not include development of a formal crash data base for other vehicles used by police involved in fires following rear impact, nor a crash database involving rear impacts or any other crashes involving the CVPI that did not result in fuel leakage or fire.

The consistent performance of the CVPI fuel tank in failure producing high speed rear impact involves crushing of the fuel tank. Crash caused forward deformation induces contact to the back of the fuel tank which in turn moves the fuel tank forward causing contact to the front of the fuel tank by the axle/differential assembly. The fuel tank gets caught between these two relatively rigid structures and is crushed. Sharp objects on the axle/differential assembly puncture the front of the fuel tank. Sharp objects in the trunk of the CVPI and sharp protrusion from deformed aft vehicle structures puncture the rear of the fuel tank. Finally, because localized crush induces deformations to the fuel tank failures at various tank closures occur. The tank closures that fail include valves located across the top of the fuel tank, the filler neck to fuel tank seal and the fuel tank sender unit.

Ford made two retrofits to the CVPI fuel tank. The retrofits include an October 2001 Technical Service Bulletin (TSB) applicable to all 1992-2002 year model Panther Car vehicles (Ford Crown Victoria and CVPI, Mercury Grand Marquis, and Lincoln Town). The Technical Service Bulletin recommends that owners wishing to improve the safety of their vehicles make two modifications: (1) replace a hexagonal-headed parking brake cable bracket mounting bolt with a rounded bolt, which would be less likely to puncture the fuel tank, and (2) to use a file or grinder to remove certain sharp tabs found on the stabilizer bar mounting brackets. The second retrofit occurred In September 2002. Ford announced an optional upgrade kit consisting of: two shields designed to cover the shock absorber mounting brackets, parking brake cable bracket mounting bolt and certain related portions of the rear axle and spring mounting brackets, another shield was designed to cover the bottom half of the differential rear cover plate, two others shields protected the fuel tank from being cut or punctured by the fuel tank mounting straps and/or mounting strap brackets, and other modifications to protect against potential puncture related to the vapor canister located below the trunk.

In addition to the retrofit Ford announced a remedial measure intended to protect the fuel tank of the vehicle from being punctured at the rear. The remedial measure made available in June 2003 is a device called a "trunk pack." The trunk pack is placed inside the deep well trunk, and includes a plastic and Kevlar material that covers the front wall of the trunk. The trunk pack serves two purposes: first, because of partitions in the trunk pack, it serves as a trunk organizer; secondly, through layers of material on its front face it prevents most objects from puncturing the rear of the fuel tank. Proper organization, or loading, of trunk equipment is a factor in the cause of tank crush, localized fuel tank deformation and fuel tank rear side punctures. Extensive and detailed recommendations regarding mounting and loading of police equipment in the CVPI deep well trunk have been developed.

Because of the aggressive effort to investigate all reported crashes involving CVPI rear impact crashes resulting in fuel leakage and/or fire the performance of vehicles with all manifestations of retrofit and utilization of evolving best practice trunk loading are evaluated. There are no known fuel tank failures that have resulted from the September 2002 retrofit shielded components. The shields provided in the September 2002 retrofit appear to have been 100% effective in preventing fuel tank puncture from objects that they cover. The shields effectively prevented puncture in every crash test they have been subjected, including two 160 kph crash tests.

Reduction in the number of puncture failures to the back area of the fuel tank from objects in the deep well trunk is also observed following investigation of OSI crashes. Since the Ford trunk pack is not in wide use, this result is primarily due to evolving best practice guidelines for deep well trunk packing. Strict adherence to evolving best practice deep well trunk packing and mounting of trunk equipment should prevent most puncture failure to the back of the fuel tank from deep well trunk equipment, but will not eliminate all failures to the fuel tank or its closures due to deep well trunk equipment or aft vehicle structures.

Because of the location and mounting of the CVPI fuel tank, persistent failures in high speed rear impact collisions occur. Persistent failures occur despite the necessary and effective September of 2002 retrofit and use of best practice trunk loading guidelines. The persistent failures include failures by (O)ther assemblies/mechanism and failures from aft vehicle structures or components. (O)ther assemblies/mechanism includes failures of the sender unit, failure of valves at the top of the fuel tank and failures to the filler neck. Structures aft of the fuel tank are deformed and cause failure of the fuel tank by crash forces and by influence from deep well trunk contents.

While the best method to prevent burn injuries is to eliminate fuel leakage in crashes that an occupant may conceivably survive, burn injuries can only occur in the proximity of a post crash burn injury producing fire. Eliminating post crash burn injuries would involve a hierarchal approach that; (1) eliminates fuel leakage (and if you do not eliminate fuel leakage, then); (2) reduce the leak size/rate of the fuel; (3) eliminate fuel ignition; (4) eliminate (or decrease the rate of) fire propagation; and (5) eliminate humans in potential fire by escape or clearing from the fires harm. The likelihood of a post crash fires ignition is dependant upon the nature, volume and flow of fuel leakage. For example, eliminating punctures to the bottom of the fuel tank – bottom punctures drain all fuel onto the ground - reduces the likelihood of fire ignition and burn injury. Assuming fuel leakage is not eliminated available systems approach fire prevention by either suppressing fire ignition or extinguishing a fire once it starts. The concept of preventing a fire from starting is the best approach consistent with the established practice of first preventing fuel leakage.

CONCLUSION

1. For rear impact crashes studied resulting in fuel tank leakage or fire, rear impact damage and corresponding equivalent Taurus rear impact speed is greater than for identical vehicles in civilian use. Vehicles sold for police use require a higher speed validation crash test for fuel system integrity. A 120 kph Taurus (or equivalent) to car 50% overlap test with police equipment placed as cargo in the trunk is presently the standard used in police car fuel containment system validation.

2. For studied rear impact crashes with fuel leakage or fire equivalent Taurus rear impact speed ranging from 60 kph to 176 kph cause failure in CVPI fuel containment systems. Crashes from the entire range of impact speed should be included in analyses. The 50th percentile, 85th percentile speed is 107 kph and 144 kph, respectively.

3. Standardized tests, including FMVSS 301 compliance, NCAP, higher speed 80 kph, 50% overlap conducted by Ford and not yet effective upgrades to the FMVSS 301, fail to reveal failure mechanism that later required modifications, retrofit and additional instructions for safe use of the CVPI fuel containment system protection system. Failure mode analysis or other competent engineering analysis is the best method for avoiding and detecting defects in a motor vehicle fuel containment system.

4. Based upon crash test results and analyses of the crash database and based upon past and advertised fuel system improvement the design principal that humans should not burn in conceivably survivable crashes is appropriate, technologically feasible and economically feasible. Fuel systems remain in need of special and continuous scrutiny with the goal of eliminating post crash fire caused burn injuries.

5. Frequency of pre-retrofit puncture failure from objects located on the axle/differential assembly and the persistence post retrofit failures affirms extensive historical knowledge regarding dangers to the behind the axle location.

6. Elimination of puncture failure in actual crashes and crash tests from retrofit shielded objects located on the differential/axle assembly demonstrated possible benefits and effectiveness of shielding and possible fuel tank toughness.

7. Extensive historical knowledge regarding rear impact crash caused fuel containment system failures is the basis for a failure mode analysis that identifies defects in the CVPI fuel containment system. The CVPI fuel containment system is inadequately protected in a crush zone.

8. While elimination of fuel leakage is the preferred method to minimize the risk of burn injury, other approaches may be necessary if fuel leakage is not eliminated. Efforts to reduce the likelihood of burn injury producing fire by reducing the nature, volume and flow of fuel leakage, eliminating fire ignition and/or propagation and eliminating exposure to fire will reduce the probability of burn injury.

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APPENDIX

Failure Count	Code	Fuel System Failue Classification			
		Location	Area	Assembly/Mechanism	Component
6	*FA1	Figure A1	(F)ront	(A)xle/Differential	(1) Parking Brake Cable Bracket Bolt
13	*FA2	Figure A1	(F)ront	(A)xle/Differential	(2) Shock Mounting Bracket
7	*FA3	Figure A1	(F)ront	(A)xle/Differential	(3) Sway Bar Mounting Bracket
0	*FA4	Figure A1	(F)ront	(A)xle/Differential	(4)Sway Bar Lower Bracket
7	*FA5	Figure A1	(F)ront	(A)xle/Differential	(5) Coil Spring Seat - Lower Mount
0	*FA6	Figure A1	(F)ront	(A)xle/Differential	(6) Coil Spring - Spring
7	*FA7	Figure A1	(F)ront	(A)xle/Differential	(7) Differential - Rear, Cover
4	*FA9	Figure A1	(F)ront	(A)xle/Differential	(9) Axle/Differential - Not Specified
3	*FBB	Figure A1	(F)ront	(B) Frame	(B) Frame
2	*FC1	Figure A1	(F)ront	(C) Tank Surrounding On Car	(1) Emmission Canister Assembly
1	*FC2	Figure A1	(F)ront	(C) Tank Surrounding On Car	(2) Cross Frame
1	*FC3	Figure A1	(F)ront	(C) Tank Surrounding On Car	(3) Strap
0	*FC4	Figure A1	(F)ront	(C) Tank Surrounding On Car	(4) Deformed Car Body
0	*FC9	Figure A1	(F)ront	(C) Tank Surrounding On Car	(9) Not Specified
1	*FDD	Figure A1	(F)ront	(D) Through And Through Penetration	(D) Through And Through Penetration
0	*FEE	Figure A1	(F)ront	(E) Object in Tank	(E) Object in Tank
4	*BA1	Figure A1	(B)ack	(A) Trunk Equiptment	(1) Mounted
8	*BA2	Figure A1	(B)ack	(A) Trunk Equiptment	(2) Unmounted
2	*BA9	Figure A1	(B)ack	(A) Trunk Equiptment	(9) Not Specified
4	*BB1	Figure A1	(B)ack	(B) Tank Surroundings On Car	(1) Strap Mount
3	*BB2	Figure A1	(B)ack	(B) Tank Surroundings On Car	(2) Deformed Car Body
0	*BB9	Figure A1	(B)ack	(B) Tank Surroundings On Car	(9) Not Specified
0	*BC1	Figure A1	(B)ack	(C) External Object	(1) Ground
2	*BC2	Figure A1	(B)ack	(C) External Object	(2) Other Vehicle
0	*BC9	Figure A1	(B)ack	(C) External Object	(9) Not Specified
0	*BDD	Figure A1	(B)ack	(D) Frame	(D) Frame
1	*BEE	Figure A1	(B)ack	(E) Object in Tank	(E) Object in Tank
0	*SAA	Figure A1	(S)eam	(A) Left	(A) Left
0	*SBB	Figure A1	(S)eam	(B) Right	(B) Right
0	*SCC	Figure A1	(S)eam	(C) Top	(C) Top
0	*SDD	Figure A1	(S)eam	(D) Botom	(D) Botom
6	*OAA	Figure A1	(O)ther	(A) Sender Unit	(A) Sender Unit
5	*OB1	Figure A1	(O)ther	(B) FLVV	(1) Seal
2	*OB2	Figure A1	(O)ther	(B) FLVV	(2) Spud
0	*OB3	Figure A1	(O)ther	(B) FLVV	(3) Body of Valve in Tank
1	*OB4	Figure A1	(O)ther	(B) FLVV	(4) Pressure Relief Vent
0	*OB9	Figure A1	(O)ther	(B) FLVV	(9) Not Specified
1	*OCC	Figure A1	(O)ther	(C) Rollover Valve	(C) Rollover Valve
1	*ODD	Figure A1	(O)ther	(D) Pressure Sensor	(D) Pressure Sensor
5	*NAA	Figure A1	Filler (N)eck	(A) Grommet Seal Broken	(A) Grommet Seal Broken
1	*NB1	Figure A1	Filler (N)eck	(B) Neck	(1) Broken
0	*NB2	Figure A1	Filler (N)eck	(B) Neck	(2) Punctured
0	*NB3	Figure A1	Filler (N)eck	(B) Neck	(3) Tether Broken
3	*NB4	Figure A1	Filler (N)eck	(B) Neck	(4) Pulled Out
1	*NB5	Figure A1	Filler (N)eck	(B) Neck	(5) Valve Broken
0	*NB9	Figure A1	Filler (N)eck	(B) Neck	(9) Not Specified
4	*999	Figure A1	(9) Not Speci	(9) Not Specified	(9) Not Specified

Table A1, Fuel System Failure Classification with Failure Counts

Left Third	Center Third	Right third	
A	B	C	Top
D	E	F	Upper Half
G	H	I	Lower Half
J	K	L	Bottom
M	N	O	Vert Position Unk

9 = Not Specified

Figure A1, Coding for FCC Location