

A Bed-Mounted Fuel Tank for GM C/K Pickup Trucks

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ABSTRACT

The sidesaddle fuel tank on 1973-1987 GM C/K pickup trucks has been the subject of extensive test and evaluation. Tests conducted by NHTSA led to the conclusion that the placement of the tank outside of the vehicle frame rail increases its susceptibility to damage and leakage during severe side impact collisions. Various alternative tank designs and placement strategies to mitigate tank leakage have been evaluated. The research reported in this paper summarizes nine tests on trucks with fuel tanks relocated to the pickup truck bed. Tests show the tank to be well protected in a side impact collision, as well as in front, rear and rollover collisions. The bed-mounted tank has been shown to survive the severe side impact conditions that caused leakage in the OEM sidesaddle tanks.

INTRODUCTION

In 1967 the National Highway Traffic Safety Administration (NHTSA) introduced the Federal Motor Vehicle Safety Standard (FMVSS) No. 301, "Fuel System Integrity" [NHTSA Part 571.301] to reduce deaths and injuries occurring from fires. Initially, the standard only applied to passenger cars, however, in 1977 light trucks were also included. The standard prescribes three full-scale tests, a frontal, rear and lateral impact, following which a maximum acceptable fuel leakage rate is specified. After the crash test, the vehicle is subjected to a 360 degree roll, during which fuel leakage must be below specified levels. The frontal impact comprises directing the subject vehicle into a flat-face, rigid barrier at a speed of 48.0 km/h (30.0 mph). For both the rear and lateral test, an 1814 kg (4000 lb) rigid-flat-faced, moving barrier impacts the stationary vehicle. The test speed is 48.0 km/h (30.0 mph) for rear impacts and 32.0 km/h (20.0 mph) for side impacts. In each test configuration the fuel tank must be filled to 90% to 95% capacity.

The General Motors C/K pickup model years spanning 1973 to 1987, employed a sidesaddle tank design in which the tank was mounted outside the vehicle's frame rails. This design was alleged by the Department of Transportation to represent a safety related defect in that the tank placement exposed the tank to more severe

damage during a side impact collision compared to vehicle designs in which the fuel tank is inside the frame rails.

In December 1992 the NHTSA Office of Defects Investigation (ODI) opened an investigation to determine if certain 1970-1991 Chevrolet C/K pickups contained a safety related defect [ODI, 1994]. Although the sidesaddle design was largely discontinued in the 1988 and later models, it persisted on a few configurations until 1991. The ODI investigation was to determine whether these full size pickups posed an unreasonable risk to safety, related to the danger of fires following crashes, with primary focus on side impact crashes. Based on ODI testing and full-scale test data provided by GM, it was concluded that the C/K trucks, to which the 301 Standard applied, were in compliance. The ODI's analysis of 1979-1993 real-world accident data suggested that the incident of fatal crashes involving fire was nominally 2.5 times higher for the C/K pickup trucks over that of its competitors. However, the ODI concluded that fatal side-impact crashes involving fire were generally more severe than the crashes specified by the FMVSS 301 standard. Crash testing disclosed that the C/K pick fuel system exceeded the leakage requirements of the 301 standard when impacted in the side by a Chevrolet Caprice traveling at 80 kph (50 mph). Competitive pickup models were found to survive this test. Test dummies in the crashed vehicles indicated that the 50 mph side impact by a Caprice did not produce excessive injury measures.

On April 9, 1993, ODI recommended a safety recall on GM pickup models with the tank mounted outside the frame rails [ODI, 1994]. Subsequent negotiation between GM and the Department of Transportation resulted in an administrative settlement in lieu of a recall. Under this March 7, 1995 settlement, GM agreed to expend \$51.355 million to improve vehicle and highway safety [NHTSA, 2001]. The settlement included \$10 million for research to improve fire safety of motor vehicles. In a subsequent judicial settlement, dated June 27, 1996 GM agreed to provide an additional \$4.1 million for motor vehicle fire safety research [Judicial District Court, 1996]. In the same settlement, the Class Plaintiffs' agreed to provide \$1 million for the design, development,

testing, and implementation of fuel system safety enhancements for the C/K trucks. This latter project has been administered by the Automotive Safety Research Institute and is the basis for this paper.

In September 1999, The Automotive Safety Research Institute (ASRI) initiated a research project to investigate possible alternatives to the existing sidesaddle fuel tank design that would improve the pickup truck's fuel tank crashworthiness under side impact loading conditions. To this end, Biokinetics and Associates Ltd. was contracted to identify, retrofit and test alternative fuel tank systems or tank protective strategies for the C/K pickup trucks. A preliminary review of the existing tank designs and readily available technologies [Keown et al, 1999] identified six possibilities, which included:

1. Adding a protective frame around the existing sidesaddle tank.
2. Installing a custom fabricated tank inside of the vehicle's frame.
3. Replacing the sidesaddle tank with an auto racing fuel cell.
4. Replacing the sidesaddle tank with an after market fuel tank installed in the spare tire wheel well located underneath the bed of the pickup aft of the rear axle.
5. Replacing the existing sidesaddle steel tank with a plastic tank designed specifically for the C/K trucks.
6. Replacing the sidesaddle tank with a bed mounted tank system.

All six alternatives were installed in 1985 to 1987 C/K pickup trucks and subjected to full-scale tests at elevated impact speeds compared to FMVSS 301 requirements [Keown et al, 2000]. Based on the favorable results obtained, the center-mounted tank and the bed-mounted tank were selected for further development and testing. This paper presents the continued development of the bed-mounted tank.

PICKUP TRUCK SELECTION

The C/K pickup trucks selected for modification and testing were chosen from the 1985 to 1987 model years. The principal reasons for this selection were that earlier models were less plentiful, were more likely to be in poor shape mechanically and were more likely to have excessive corrosion of the frame. All the trucks were purchased in or around the city of Ottawa, Canada, where the use of road salt in the winter accelerates the corrosion of vehicles. A certain amount of corrosion was present on each truck in the test program. However, to reduce the variability in the testing, trucks with extreme frame corrosion were excluded.

The condition of similar trucks from regions with milder winters and where road salt is not used would no doubt have less corrosion. However, the trucks that were used were considered to represent a less than optimal vehicle condition that would typify corrosion levels more severe than most 1985 and later C/K trucks currently on the road. Hence any tank system that performed adequately

on the tested trucks would likely perform equally well on a less corroded vehicle.

The 1973 to 1987 line of C/K trucks were available in two and four-wheel drive with a short or long bed and three maximum payload ratings that included $\frac{1}{2}$ ton, $\frac{3}{4}$ ton and 1 ton. Each of the eight trucks purchased for the development of the bed-mounted tank were the two-wheeled drive, $\frac{1}{2}$ ton (1500 series), long bed version. These selected trucks were the most numerous in service and were considered to be the least durable in a crash.

POSITIONING OF THE BED-MOUNTED TANK

The ODI study had concluded that the fuel tank located in the sidesaddle position results in increased risk of fuel leakage in side impact crashes. One objective of the tank relocation strategy was to install the tank in a position in which it would be less susceptible to direct loading from an impacting vehicle. By mounting a tank system in the bed of the truck, it would be both higher than typical bumper and frame heights on most vehicles and it would gain additional clearance from the side of the truck, effectively removing the tank from direct loading and avoiding undue damage. Additionally, the structure of the cab and of the bed itself would add to the protection afforded to such a system. However, such an installation reduces the capacity of the bed and limits some of its functions.

A bed-mounted tank system was installed behind the truck cab in eight GM pickup trucks. A secondary tank system was also installed on seven of these trucks. The secondary tank system consisted of either a custom fabricated tank installed in between the frame rails or a tank installed in the sidesaddle location. A fuel line switching valve was installed for each truck with a secondary tank such that the truck could function from either system. The performance of the alternate tanks is reported on separately [Keown et al, 2000; Fournier et al, Oct. 2001].

Various after market bed-mounted auxiliary tanks were evaluated for use in the first test. The specifications for the tank selected are summarized in Table 1. The tank was held in place by four bolts: two fastening the tank to the floor of the truck bed and two fastening it to the front wall of the bed.

All subsequent bed-mounted systems consisted of relocating a standard OEM steel tank and brackets, normally installed in the sidesaddle position, into the bed of the truck. Standard mounting brackets were used with additional holes drilled in the brackets such that they could be bolted vertically into the floor of the truck bed. A typical installation is shown in Figure 1.

Table 1: Specifications of the after market tank .

Supplier	Auxiliary Truck Accessories 13211 Bee Street Dallas, Texas 75243
Material	Aluminum
Thickness	3.2 mm
Weight of Tank	29.5 kg
Capacity	189 litres

The tank was covered by a 1/8 inch thick aluminum checker plate shield for protection from shifting cargo. The shield installation is shown in Figure 2. The shield weighed 35 lbs and cost approximately \$215. Other miscellaneous hardware required for the bed installation cost \$40. The installation time for the bed tank and shield was 3 hours. Installation procedures for the bed-mounted tank were documented in a report [Fournier et al, Dec. 2001]. In some tests the tank was left exposed so that it would be visible from overhead camera views.



Figure 1: OEM bed tank installation with OEM brackets



Figure 2: Typical in-bed installation of an OEM tank with shield.

The fuel delivery and vent lines for both the after market tank and the bed-mounted OEM tank were routed downwards from the top of the tank to a hole drilled in the floor of truck bed, located between the tank and the front wall of the bed. The after market tank was filled directly through a gas cap located on top of the tank while a filler neck and cap were fastened to the inside top edge of the truck bed for the OEM tank. A filler neck reverse flow check valve was installed on several of the OEM tank systems. However, its functionality was never exercised during the tests.

TEST CONFIGURATIONS

The crashworthiness of the bed-mounted tank systems was evaluated under various full-scale crash configurations. A bullet vehicle comprised of either a Chevrolet Caprice or a FMVSS 301 moving barrier collided into the side of a stationary GM 1500 series pickup truck retrofitted with the bed-mounted tank. In the Caprice tests, the angle of impact was 60° from the front of the truck and inline with a point on the truck's centerline located between the cab and the truck bed. In one test the Caprice was replaced with a FMVSS 301 rigid-face moving barrier oriented perpendicularly to the longitudinal axis of the truck and centered on the space between the truck bed and the cab. Typical vehicle alignment for the Caprice and moving barrier tests are shown in Figure 3 and Figure 4.

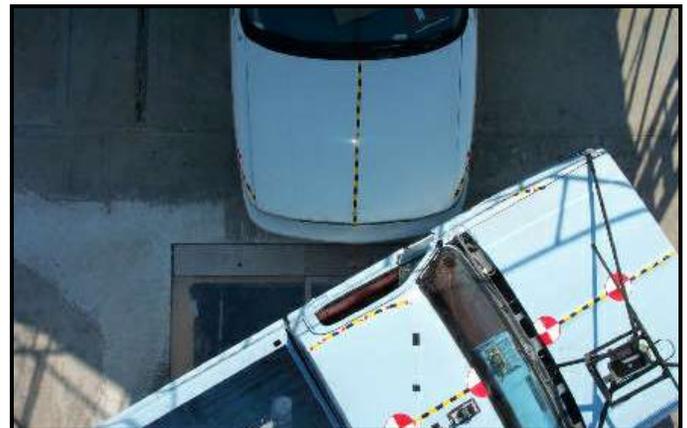


Figure 3: Typical vehicle alignment in side impact tests from a Caprice.



Figure 4: Alignment for the side impact barrier test.

Tests conducted with the Chevrolet Caprice as the bullet vehicle replicated as much as possible one of the vehicle to truck configurations used by the ODI during its investigation into the sidesaddle fuel tanks. This test was conducted at the Vehicle Research and Test Center (VRTC) and the test parameters were documented in the Transportation Research Center Inc.'s (TRC) test report No. 930324 [Markusic, 1993].

The ride height of the Caprice bullet vehicles was adjusted to compensate for braking. VRTC had determined that under heavy braking the front of the vehicle lowered by 73.7 mm as measured from the front bumper centerline and the rear of the vehicle raised up by 63.5 mm as measured from the centerline of the rear bumper. To achieve this braking attitude a level ride was first established and then the front and rear axles were loaded and unloaded respectively to correspond to the pre-test attitude reported in TRC's Report 930324.

Two frontal and two rear impact barrier tests were also performed following test procedures similar to those specified in the FMVSS 301 safety standard with the exception of impact speeds that at times were elevated from those specified. The two frontal barrier tests consisted of a truck colliding perpendicularly into a rigid immovable flat wall. Similarly, two rear impact tests were performed with a stationary truck being struck from the rear by a moving FMVSS 301 rigid barrier.

To verify that a truck's baseline stability and handling characteristics were not adversely affected by placing a fuel tank in the bed of the truck, both a dynamic rollover test and a handling test were performed.

The rollover test was performed as per FMVSS 208. The truck was mounted on a cart at an angle of 23° with the driver's side elevated such that the longitudinal axis of the truck was perpendicular to the direction of cart travel (see Figure 5). The cart was accelerated down the test track and the truck was released and allowed to roll.



Figure 5: Pickup truck mounted on a FMVSS 208 rollover test cart.

The handling test consisted of subjecting a pickup truck, with a bed-mounted tank, to a series of abrupt driving maneuvers. The effects of different tank fill levels and tank baffling on the trucks handling characteristics were evaluated.

PASS/FAIL ASSESSMENT

Following a test, a tank system that complied with the leakage requirements specified in the FMVSS 301 standard was considered to have passed the crash test. If the post crash fuel leakage was within the specified limits, the integrity of the center-mounted tank was further verified, as per the standard, by inverting the entire truck about the longitudinal axis in increments of 90°. The

leakage rates during the inversion were again compared to the allowable limits specified in the FMVSS 301 standard.

All of the tests performed were research oriented and did not comply with all the procedures set forth in the FMVSS 301 standard. For example, either the collision speed or the selection of the bullet vehicle varied from that specified. Consequently, compliance with the leakage requirements alone did not infer compliance with the standard. Ultimately, tests were conducted in all crash directions required by FMVSS 301, but were at higher crash severities than specified by the standard.

CINEMATOGRAPHY

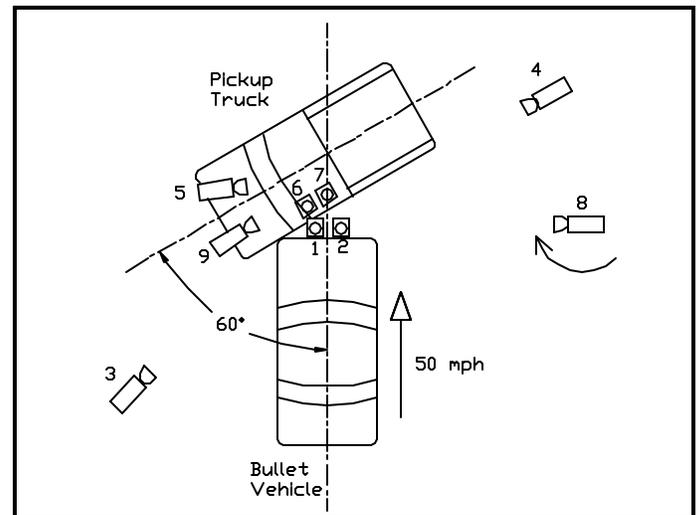


Figure 6: Vehicle orientation and camera positions for lateral impact tests (some tests are the mirror image of that shown).

The positioning of the cameras are depicted in Figure 6. Seven high-speed film cameras were set up to record the side impact tests. These included two overhead shots, two underside shots from a pit, one left shot, one right shot and one onboard shot to record occupant movement. For some tests a second onboard high-speed camera was used. Furthermore, a real-time video camera was used to follow the bullet vehicle to the impact. The framing rate for the cameras was 500 frames per second (fps) except for one pit camera that filmed at 1000 fps.

Seven cameras were also used for the barrier and dynamic rollover tests. For the barrier tests, these included; two cameras on each side of the truck perpendicular to the line of travel, two cameras underneath the truck and one overhead. During the dynamic rollover test six cameras were positioned along the test track to capture the entire tumbling event and one camera was situated inside the truck cab with a view of the driver's head and the roof liner. As previously noted, all cameras recorded at 500 fps except for one underside camera that recorded at 1000 fps. In all cases a real time camera recorded the entire event.

RESULTS

The seven full-scale crash tests were conducted at PMG Technologies' facility in Blainville, Quebec, Canada. The handling test and the dynamic rollover test were conducted at TRC's test facility in East Liberty, Ohio. The configuration and success of each test is summarized in Table 2, which is followed by a brief description of the each result. In most of the tests a second tank was also installed on the vehicle. In the

Table 2: Summary of the test program.

Test No.	Test Configuration	Impact Speed		Fuel Leakage (pass/fail)
		(km/h)	(mph)	
RP 01-011	60° side impact by a Caprice	81.3	50.8	Pass
RP 01-036	60° side impact by a Caprice	81.4	50.9	Pass
RP 01-037	90° side impact by a rigid barrier	64.2	40.1	Pass
RP 02-028	Frontal into rigid barrier	49.0	30.6	Pass
RP 02-029	Rear impact: moving rigid barrier	49.0	30.6	Pass
RP 02-031	Rear impact: moving rigid barrier	56.2	35.1	Pass
RP 02-032	Frontal into rigid barrier	51.8	32.4	Pass
20010462	Handling test	Na	Na	Na
011024	Dynamic rollover test	50.2	31.4	Pass

TEST RP 01-011

The bullet vehicle for this test was a Chevrolet Caprice. The bed-mounted tank was an aftermarket tank described in Table 1. During impact, the truck was lifted off the ground and carried laterally on the hood of the Caprice. In the process, a second plastic tank installed in the sidesaddle position was ejected from the truck sustaining significant tearing damage and substantial fuel loss.

The damage to the truck was predominately centered forward of the front wall of the bed and below the level of the bed floor. The front left corner of the bed floor showed signs of minor buckling, however, the region of the truck box immediately adjacent to the bed-mounted tank was not damaged. Consequently, there was no damage to the tank and therefore it successfully passed the test.

TEST RP 01-036

The bullet vehicle in this test was also a Chevrolet Caprice. The OEM bed-mounted tank did not sustain.



Figure 7: Post test view of bed mounted tank (test RP 01-036).

any damage during the collision, however all of its contents were siphoned when the alternate tank switching valve was crushed between the frame rail and transmission housing. Damage to the switching valve effectively severed the fuel lines leading to the engine from both tanks. Notwithstanding the damage to the switching valve, the bed-mounted tank itself was completely unscathed, as is shown in Figure 7. If it had been the only tank installed the observed spillage from the switching valve could not have occurred. The test indicated the need for improved protection of the switching valve for vehicles equipped with two tanks.

TEST RP 01-037

Unlike the previous two tests, the bullet vehicle in this test was a FMVSS 301 rigid moving barrier oriented with its longitudinal axis normal to the longitudinal axis of the

truck, centered on the space between the cab and the box.

The requirements of FMVSS 301 are such that the barrier must impact the target vehicle at 32.0 km/h (20.0 mph). This low impact speed was not expected to produce significant intrusion into the pickup. Therefore, for a more stringent test of the tank system a substantially higher impact speed of 64.0 km/h (40.0 mph) was chosen.

The alignment of the barrier was such that the crush zone on the truck was aft of the A-pillar and forward of the rear axle. In avoiding these two rigid elements of the truck, maximum loading of the tank systems was achieved.

The depth of crush caused by the barrier was sufficient for the inside bed wall to contact the tank and cause the tank to shift in its mounting brackets. A sharp thread from the OEM mounting strap induced a minute crack in the top of the tank. The resulting leakage was within the allowed limits, which was confirmed by an inversion test. It was evident that added protection could be achieved by reducing the aggressiveness of the mounting threads.

TEST RP 02-028

This test was performed according to the frontal test procedures of FMVSS 301 which necessitated bolting a 145.1 kg ballast mass to the bed floor and an impact speed of 48.0 km/h (30.0 mph). Inertial loading from the bed-mounted tank itself led to elastic deformation of tank's mounting brackets, which tilted forward contacting the front of the box. No permanent deformation was recorded and the tank and brackets remained securely attached to the bed. Following the collision, the integrity of the bed-mounted tank remained intact, which was subsequently confirmed with an inversion test.

TEST RP 02-029

This test was performed according to the rear impact barrier requirement of the FMVSS 301 standard, which in this case required a 146.9 kg ballast mass to be bolted to the bed floor and an impact speed of 48.0 km/hr (30.0 mph). The bed mounted tank in this test was covered, but from the movement of the cover it can be deduced that the tank and the mounting brackets probably tilted rearward from inertial loading upon impact from the barrier. The overhead film revealed that the cover briefly pulled away from the front of the truck box indicating internal loading from the tank and brackets. Following the test the tank mounting brackets remained intact and there were no leaks in the fuel tank system.

TEST RP 02-031

This test was also a rear impact barrier test performed similarly to test RP 02-029 with three exceptions. Firstly, a spare tire was installed underneath the truck aft of the rear axle, whereas with every other truck the spare tire was missing. Secondly, there was no ballast weight attached to the bed of the truck. Thirdly, the impact speed was increased from 48.0 km/h (30.0 mph) to 56.0 km/h (35 mph).

During the test, the bed-mounted tank's cover sustained permanent deformation. The cover, which normally fits snugly to the box floor and the front wall, was deformed from distortion of the truck box. The integrity of the bed-mounted tank, however, remained intact.

TEST RP 02-032

This frontal barrier test was performed similarly to test RP 02-028 with two exceptions. First, the test speed was increased to 51.2 km/h (32.0 mph) from 48.0 km/h (30.0 mph) and secondly, the ballast weight that was bolted to the floor of the box in the previous frontal test was replaced by 146.9 kg of unrestrained plywood. There was approximately 152.4 mm of clearance between the wood and the tank cover. This type of loose payload was considered to be representative of the loads that would be experienced by the protective cover in an impact.

As expected, the plywood payload slid forward and impacted the cover over the bed-mounted tank creating a depression in its vertical face. Upon removal of the cover following the test there were no leaks or noticeable damage to the tank.

TEST 011024

A pickup truck with a bed-mounted tank was mounted on an FMVSS 208 rollover test cart at an angle of 23° with the passenger side of the truck facing the direction of cart travel. The test setup is shown in Figure 5. The truck and cart combination was accelerated up to a speed of 50.7 km/h (31.7 mph) when the truck was released. The passenger side of the truck contacted the ground first and was followed by one complete revolution with the truck coming to rest on its four tires.

The bed mounted tank and its components were well protected and were not damaged during the rollover event. The integrity of the tank was confirmed with a FMVSS 301 inversion test performed on the tested truck. No leaks were recorded.

TEST 20010462

A pickup truck with a bed-mounted tank and outfitted with safety outriggers was subjected to a series of four abrupt driving maneuvers by an experienced test driver. The purpose of these maneuvers was to evaluate the effects

of fuel sloshing on vehicle stability. The four handling maneuvers included:

- Double Lane Change.
- “J” Turn.
- Slalom.
- Resonant steer.

Initially, an empty bed-mounted tank without baffles was evaluated to provide a baseline for comparative purposes. The tank was then filled to half its capacity and finally to full capacity. An additional test was performed with the tank filled to half capacity with the inclusion of internal tank baffling. The baffling was incorporated by introducing porous aluminum spheres into the tank. The spheres, provided by Explosafe, filled the tank’s entire volume but only decreased its capacity by less than 2%.

For each handling maneuver the driver provided subjective feedback with regards to variations in the trucks handling characteristics as they related to the various tank fill levels or the inclusion of tank baffling. The driver’s feedback suggested that the differences in handling were minor and were likely related to the additional fluid mass and not to fluid movement. Additionally, the driver indicated that there was no difference in handling with the introduction of tank baffling.

DISCUSSIONS

LATERAL IMPACTS

The input parameters for the two side impact tests with the Chevrolet Caprices were very similar. The vehicle alignment at impact was within 45.7 mm horizontally and 35.6 mm vertically from the static pre-crash alignment and the impact speeds were almost identical at 81.4 km/h (50.9 mph) and 81.3 km/h (50.8mph). The test weight of the trucks and bullet vehicles including the test dummies were 1995.6 kg and 2003.5 kg for the trucks and 1812.3 kg and 1815.2 kg for the Caprices. Additionally, the ride height of the two trucks was within 2.5 mm of each other; the same is true for the two bullet vehicles.

It is not surprising, considering these similarities, that the kinematics of each test were very similar. Following contact with the truck, the front end of the bullet vehicle was pushed downwards and as it travelled under the truck it lifted the truck up and carried it in the direction of impact. The resulting damage to the two vehicles was similar and is shown in **Figure 8**.

The integrity of the auxiliary and the OEM tanks installed in the bed of the truck was unaffected by the impact from the Caprices. The obvious reason for the lack of damage is that the location of the bed-mounted tank is well above the crush zone typically caused by a Caprice.



Figure 8: Typical damage to a GM pickup truck following a side impact from a Caprice.

Unlike the Caprice, the impacting surface of the FMVSS 301 rigid barrier extends well above the height of the bed-mounted tanks. Consequently, the resulting vehicle crush from the barrier encompassed the side of the truck immediately adjacent the bed-mounted tank installation. However, because of the distributed nature of the barrier loading, the actual penetration into the bed was minimal, although it was sufficient to shift the tank in its mounting brackets thus causing damage to the tank resulting in a minor fuel leak. Keeping in mind that the test with the rigid barrier was performed at substantially elevated impact speeds, the tank still complied with the leakage requirements specified in the FMVSS 301 standard.

FRONTAL AND REAR IMPACTS

By virtue of its location, the bed-mounted tank did not sustain any damage in either the FMVSS 301 style frontal or rear impact tests. Even at elevated speeds compared to those specified in the standard the bed-mounted tank remained intact following the test. The tank and mounting brackets tilted back and forth under its own inertial loading but no permanent damage or deformation to the tank itself was observed.

The tank cover did sustain permanent deformation resulting from the deformation of the truck box and/or from a shifting payload in the case of test RP 02-032. However, the tank remained intact.

CHANGE IN THE TRUCK'S CENTER OF GRAVITY

The placement of a fuel tank in the bed of a truck increases the height above ground of the truck's centre of gravity (CG). Furthermore, when cornering, the lateral orientation of the tank permitted fuel to slosh from side to side if the tank did not have internal baffles. Conceivably the change in CG location and the fuel sloshing from side to side could affect the stability and handling of the truck.

An analysis of the expected vertical change in the position of a truck's CG and its influence on the Static Stability Factor (SSF) was performed. Baseline vehicle information was obtained from measurements recorded in the NHTSA's database on vehicle inertial parameters,

which specified vehicle weights and the height of their CG above ground [Heydinger, 1999]. Seven trucks from the database were included in the analysis, each of which had a filled sidesaddle tank installed. The cited values from the database were not corrected for the removal of the sidesaddle tank that would accompany the installation of the bed-mounted tank system.

The estimated change in the trucks' CG and SSF were calculated based on a bed-mounted tank system installed in the truck bed having a total mass of 91.0 kg, which includes the tank, brackets, shield and 76.0 l of fuel. The SSF was calculated according to the following formula:

$$SSF = \frac{T}{2H}$$

where,

T vehicle track width
H vehicle CG height

Table 3: Change in SSF when a tank is installed in the truck bed.

Truck	Static Stability Factor (SSF)		
	Initial	With bed tank	% difference
1981 Chev. C-20	1.22	1.21	1.3
1982 Chev. C-10	1.25	1.23	1.4
1982 Chev. K-20	1.19	1.17	1.3
1985 Chev. K-20	1.14	1.13	1.1
1985 GMC C-15	1.23	1.21	1.4
1987 Chev. C-15	1.12	1.12	0.7
1987 Chev. C-15	1.19	1.17	1.3
1987 GMC 1500	1.12	1.11	1.1
1987 GMC Dually	1.21	1.20	1.2

Changes to the trucks' SSF are presented in **Table 3**.

With a maximum change in the SSF of 1.4%, as indicated in **Table 3**, the increase in CG height from the installation of a bed-mounted tank does not adversely or significantly affect the roll-over stability characteristics of the trucks. This was confirmed by the handling test performed at TRC with a GM pickup truck outfitted with a bed-mounted tank. As reported previously the differences in handling between various bed tank fill conditions were minor.

SUMMARY

A bed-mounted fuel tank system, shown in **Figure 9**, was tested on eight GM 1500 series pickup trucks. The first system consisted of an after market auxiliary bed-mounted tank, while the later seven systems

consisted of an OEM standard side mounted tank with the mounting brackets relocated to the bed of the truck.



Figure 9: Bed mounted tank with components.

Each type of tank system was installed in a truck that was impacted on the side by a Chevrolet Caprice angled at 60° from the front of the truck and travelling at nominally 80.0 km/h (50.0 mph). Neither system was damaged during the testing and no fuel leakage from the tank was observed.

One of the seven trucks that was retrofitted with an OEM tank and brackets relocated to the bed of the truck, was impacted in the side by a FMVSS 301 rigid moving barrier travelling at 64.2 km (40.1mph), twice the speed required by the FMVSS 301 standard. A small leak was discovered after the test. However, the rate of leakage was within FMVSS 301 acceptable limits.

In addition to the lateral impacts, two of the trucks were collided into an immovable rigid barrier and two trucks were impacted in the rear by a FMVSS 301 moving barrier. In all four cases the bed mounted tanks remained unscathed with damage limited to the cover placed over the tanks to protect them from a shifting payload.

Concerns regarding possible negative effects of changes in a truck's center of gravity and sloshing of the fuel in a bed-mounted tank on vehicle stability were unsubstantiated through a series of four abrupt driving maneuvers with the tank filled to various capacities, with and without baffling. The test driver provided a subjective evaluation of the variation in the truck's handling characteristics under various tank fill conditions and concluded that the differences in handling were minor.

A dynamic rollover test was performed on the same truck that was used for the handling test. The bed mounted tank and its components were well protected in the bed of the truck and did not sustain any damage or leakage.

The test reports and test videos of each individual crash test were documented on a CD (Biokinetics, March 2002) that is available from the Automotive Safety Research Institute.

Generally speaking the bed-mounted tank system is a viable alternative to the sidesaddle tank system. In this location it has been shown to be well protected in a

variety of crash configurations that include frontal, rear and lateral impacts and in a dynamic rollover condition.

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