Howell, Rosa (NHTSA)

From: Hershman, Larry (NHTSA)
Sent: Wednesday, January 20, 2010 10:09 AM
To: Howell, Rosa (NHTSA)
Cc: Yon, Scott (NHTSA)
Subject: FW: Grand Cherokee Vulnerable Fuel Hose & Lines
Attachments: MVFRI Fuel Filler Tube Leakage Test Report.pdf; 2004 Jeep Grand Cherokee Fuel Hose Under Frame Rail.JPG; ZJ_FFH-1.JPG; ZJ_FFH-4.JPG; ZJ_FFH-2.JPG; ZJ_FFH-3.JPG; ZJ_Mesh_Close-up.JPG; ZJ_FFH_Part_Label-1.JPG

Rosa,
Please add this email and its attachments to the file for DP09005 Jeep Grand Cherokee.
Thanks,
Larry

From: Demeter, Kathleen (NHTSA)
Sent: Wednesday, January 20, 2010 9:18 AM
To: Hershman, Larry (NHTSA)
Subject: FW: Grand Cherokee Vulnerable Fuel Hose & Lines

More for the file

From: Clarence Ditlow [mailto:cmdiii@autosafety.org]
Sent: Tuesday, January 19, 2010 11:22 PM
To: Demeter, Kathleen (NHTSA)
Cc: Yon, Scott (NHTSA); KDIGGES@aol.com
Subject: Grand Cherokee Vulnerable Fuel Hose & Lines

Fuel system engineering is not rocket science –safe fuel system technologies have been know and used since the early 1960's. Like real estate, the three most important factors are location, location and location. If an auto company has a safe location for major fuel system components like the filler neck, filler tube, vent tube and fuel tank, then the engineering job is simpler. If one has a unsafe location like a fuel tank located outside the fuel rail or a filler neck protruding outside the body panels, then one has to use additional safety features such as multiple check valves, steel or braided steel fuel lines and hoses and tank bladders to make the fuel system safer. Failure to have a filler hose/fuel tank/vent line check valve is not as necessary if the tank and filler tube and tank and vent lines are so well joined, located and protected that the filler hose is never severed or dislocated from the tank.

One of the Grand Cherokee's fuel system defects is a rubber fuel filler hose and vent line located in a vulnerable position where it can be severed or dislocated. The attached Disconnected Fuel Lines Leakage Test Report from MVFRI demonstrates that the Grand Cherokee has massive fuel leakage when the fuel lines are disconnected with leakage 35 times greater than allowed by FMVSS. Attached are photos showing the fuel hose going under the frame. The remaining photos are of the an OEM 1993-98 rubber fuel filler hose purchased from a Chrysler dealer and an OEM 1998-04 rubber fuel filler hose also purchased from a Chrysler dealer.

Litigation deposition of Judson Estes on a 1997 Grand Cherokee reveals that Chrysler had major concerns about running the fuel hose & vent lines through the frame rail such that Chrysler added a bracket: "The true intent of the bracket was to prevent contact with the fill and vent lines on the body frame rail where they went through." Mr Estes also testified that adding the bracket had a unplanned beneficial effect: "Where the tank hits the differential is raised by introducing the side bracket on the left side. That bracket helps the tank rise over the differential. It still contacts the differential, and the contact with the differential is still in the same place on the tank. . . . Yeah. The intent of the bracket was to prevent the pass-through hole from closing at all on the fill and vent

lines, and after the test, we noted that it performed what to us was somewhat in an unanticipated way, that it lifted the tank up and over the axle. It was one of those things that went, well, it did what we thought we wanted it to do and we got this nice side benefit as well." (Please note that fuel tank differential impact was so common in Chrysler crash tests that Chrysler engineers stopped recording that observation because it was routine for the tank to hit the differential.

Note that Mr Estes essentially confirmed the MVFRI Disconnected fuel lines and hoses report. Q. "the 5380 test report states under Post Test Remarks, "There was excessive fuel leakage during impact and the subsequent 30 minutes, resulting from partial separation of the vent line fitting from the tank." Have I read that accurately?
A Yes, ma'am. Q Now, are you telling us that the vent line fitting separation occurred because of the change in the frame rail's movement during the impact portion of the test? In other words, the frame rail where the vent line and fitting fuel line pass-through moved in such a way that you believe they helped separate the vent line from the tank?
A Moved and crushed, and, yes, I do believe that that was one of the contributing factors. Now, that's just my belief, and I think that that's the way it happened."

When Chrysler moved the fuel hose and vent line from going through the frame rail to passing under the frame rail, it was jumping out of the frying pan into the fire. One cannot imagine a more vulnerable location for a rubber filler hose than under the frame rail.

Please advise if you have any questions about these materials.

Clarence Ditlow
Executive Director
Center for Auto Safety
1825 Connecticut Ave NW
Washington DC 20009

Tracking:

Recipient	Read
Howell, Rosa (NHTSA)	Read: 1/20/2010 10:59 AM
Yon, Scott (NHTSA)	Read: 1/20/2010 1:23 PM

DP09-005

MEMO 1-20-2010

JEEP GRAND CHEROKEE VULNERABLE FUEL HOSE & LINE

MVFRI Fuel Filler Tube Leakage Test Report

BIOKINETICS AND ASSOCIATES LTD.

Comparisons of Internal Tank Components – 20 Fuel Systems

Report No.:
R04-06 v02

Date:
2004 – 07 – 26

Status:

Prepared for:
Dr. Ken Digges

Motor Vehicle Fire Research Institute
1334 Pendleton Court
Charlottesville, Virginia 22901

Authors:
Ed Fournier
Jim Kot

Biokinetics and Associates Ltd.
2470 Don Reid Drive
Ottawa, Ontario, K1H 1E1
Canada

tel: (613) 736-0384
fax: (613) 736-0990
www.biokinetics.com

Preface

This report constitutes a final deliverable for Biokinetics and Associates' contract with the Motor Vehicle Fire Research Institute to carry out the work described in Biokinetics' proposal P04-27.

The opinions expressed herein are those of Biokinetics and Associates Ltd. and do not necessarily reflect those of the Motor Vehicle Fire Research Institute.

Table of Contents

List of Figures and Tables

1. Introduction

In the ongoing effort to support the review of fuel system technologies, MVFRI has contracted Biokinetics to investigate fuel fed fire potential through the analysis of fuel tank technologies. To this end, Biokinetics has conducted leakage tests on 20 fuel tanks to study the fuel containment technologies employed and their performance. The tests simulated a vehicle rollover by rotating a tank, filled to capacity, about an axis that when installed in a vehicle would be parallel to the vehicle's longitudinal axis. The tanks were filled with water instead of gasoline or Stoddard which is typically used in automotive testing. It was understood that the properties of these liquids are different, however, it was believed that any leakage encountered solely because of the difference between the liquids would be negligible. Nevertheless, liquid soap was added to the water to reduce surface tension and promote capillary flow as much as possible.

The tanks were rotated to eight discreet positions during the rollover simulation. In each position the fuel system hoses were disconnected one at a time to represent a damaged or severed line and the resulting leaks were observed. The results of the testing where varied with some tanks leaking in every orientation and others not leaking at all.

The connections to the tank systems were compared to ascertain the design features or components that may have influenced the amount of leakage observed. The comparisons were extended to include internal features that could only be accessed by cutting the tanks open. The results of the design evaluations and component comparisons are described in this report.

2. Results

The results of the rollover leak tests, reported in a previous Biokinetics Report [Ref. 1], are repeated in Table 1 below which indicates the occurrence of a leak. However, it does not identify the source of the leak, in fact, for a given tank orientation the tanks may have leaked from more than one source. A more detailed breakdown indicating the source of leakage for the individual tanks is presented in Appendix A.

Table 1: Summary of leak test results.

Vehicle	**Tank Orientation**							
	0^o	60^o	90^o	120^o	180^o	210^o	270^o	300^o
Acura 3.2 TL / Honda Accord	N	Y	Y	Y	Y	Y	Y	N
Audi A8	Y	Y	Y	Y	Y	Y	Y	Y
BMW 325i	N	N	N	N	Y	Y	Y	Y
Chevrolet Corvette	Y	Y	Y	Y	Y	Y	Y	Y
Chrysler Cirrus (Stratus)	N	N	N	N	N	N	N	N
Dodge Neon	N	N	N	N	N	N	N	N
Ford Mustang	N	N	N	N	N	N	N	N
GMC Sierra	N	Y	Y	Y	Y	Y	Y	Y
Honda Odyssey	N	Y	Y	Y	Y	Y	Y	N
Jeep Cherokee	Y	N	N	Y	Y	Y	Y	Y
KIA Spectra	N	N	N	N	N	N	N	N
Mazda MPV	Y	Y	Y	Y	Y	Y	Y	Y
Mercury Grand Marquis	N	Y	Y	N	N	N	N	Y
Plymouth Grand Voyager	N	Y	Y	Y	Y	Y	Y	Y
Toyota Camry	Y	Y	Y	Y	Y	Y	Y	Y
Toyota Corolla	Y	Y	Y	Y	Y	Y	Y	Y
Toyota Prius	N	Y	Y	Y	Y	Y	Y	Y
VW Jetta	N	Y	Y	Y	Y	Y	Y	Y
Mercedes S430	Y	Y	Y	Y	Y	Y	Y	Y
Saturn SL	N	N	N	N	Y	Y	Y	Y

The performance of a fuel system is regulated by the FMVSS Standard 301: "Fuel System Integrity" which prescribes a series of impact tests that include frontal, lateral and rear impacts to the vehicle. Subsequent to the impact, FMVSS 301 permits a maximum acceptable fuel leakage rate of 28 g per minute in the upright orientation and successive 90^{o} rollover increments. As a point of reference the leakage observed in the tank system rollover tests can be compared to the 28 g per minute cited in FMVSS 301.

Presumably, each vehicle included in the leak test matrix complies with FMVSS 301, which suggests that the damage simulated in the leak tests is more severe and not representative of damage typically encountered during FMVSS 301 testing. Nevertheless, the results of the testing may be instructive as to the effectiveness of various tank components or designs under catastrophic damage to the fuel lines and hoses that may occur in real world collisions.

2.1 Observations: Leak Testing

The following observations stem from a review of the fuel system leak test results.

- For the most part, all of the leakages observed in the tank system rollover tests were greatly in excess of the 28 g per minute which is the maximum rate permitted in the FMVSS 301 standard.
- None of the tank systems leaked if the fuel lines and hoses remained intact. In general, leakage only occurred when a fuel line was disconnected to represent a severed line or hose. Lines and hoses were disconnected one at a time.
- Leakage that occurred in the upright (0^{o}) orientation stemmed from lines and hoses that were connected to the tank below the fluid fill level. This is commonly referred to as "siphoning."
- In some cases the leakage rates reduced after several minutes due to a vacuum build up in the ullage of the tank.
- Six tanks leaked in each of the tank orientations.
- Four tanks did not leak in any combination of severed hoses and tank orientation.
- Three of the four vehicles that had no leakage, in any orientation, exhibit a high fire occurrence rate according to a review of FARS data [Ref. 2]. The fourth vehicle was not represented in the review. The review of the FARS data does not, at this time, link the incidents of fire with fuel spillage following a crash. However, assuming fuel spillage is a contributing factor, the leak test findings indicate that crashworthiness of the vehicle and/or that of the system installation may be a significant contributing factor in post crash vehicle fires.
- According to the FARS review, three of the tank systems that leaked in all test orientations exhibit a low fire rate. Once again, it has not been ascertained whether the incidence of fire in the FARS review are related to fuel spillage. The fact that the tanks that perform poorly in the leak tests have lower fire rates strengthens the argument that vehicle and/or tank system crashworthiness is an important consideration in preventing post crash fires.

3. Design and Component Comparison

The tanks listed in Table 1 were cut open to determine which components or design strategies were effective at preventing fuel spillage if the hoses connected to the tank were compromised. In most tanks, filler neck check valves and rollover valves were employed to stem the flow of leaked fuel if the tank's lines or hoses were damaged. The tank components and their effectiveness are discussed in the following sections.

3.1 Filler Check Valves – Tank Interior

A check valve was installed inside 15 of the 20 tanks that were leak tested. In 14 of those tanks the valves were normally closed and would open under fluid pressure to allow for refuelling. Reverse flow of the fuel would act to keep the valve closed.

The check valve mechanisms observed can be divided into three categories; a spring loaded plunger, flap door mechanism and a ball/float arrangement. Examples of each type of valve mechanisms that were removed from the tanks are shown in Figure 1 to Figure 3.

a)

b)

c)

Figure 1: Spring and plunger type check valves from: a) Dodge Neon, b) Chrysler Cirrus and c) VW Jetta.

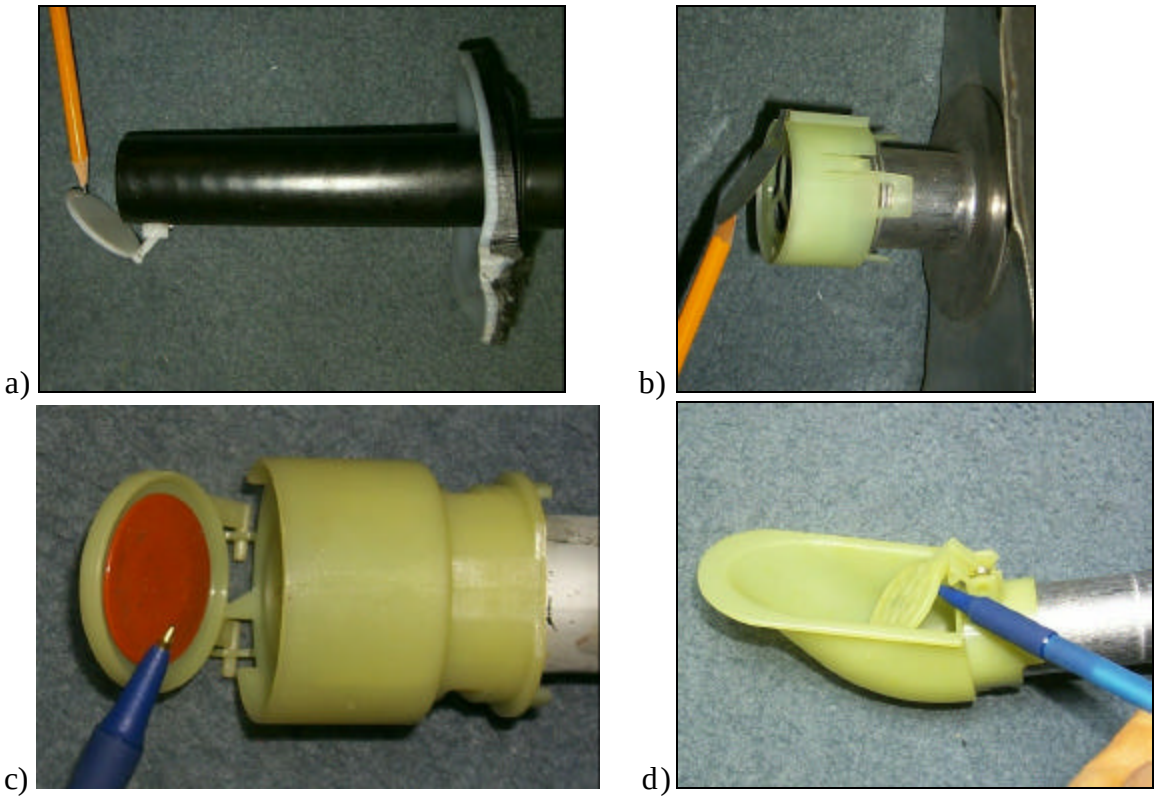


Figure 2: Flap door mechanism check valves from: a) Honda Odyssey, b) Toyota Corolla, c) Kia Spectra and d) Acura 3.2 Tl.

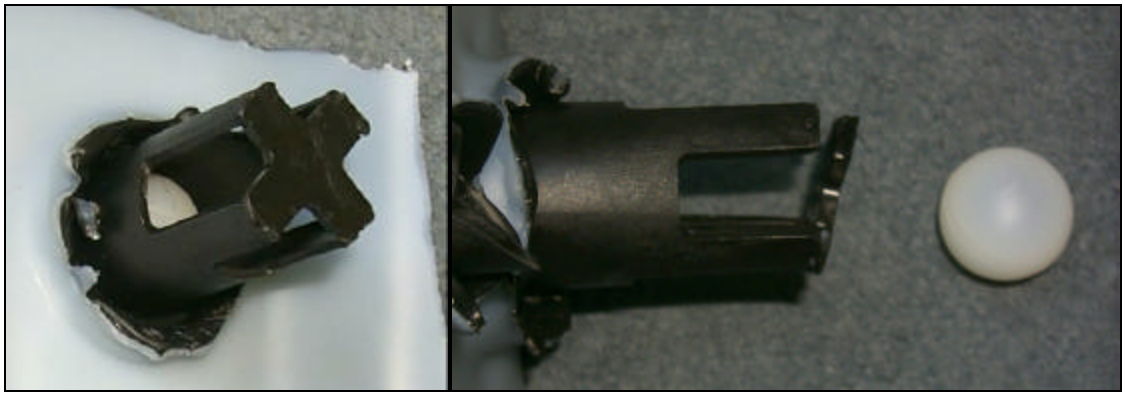


Figure 3: Float type check valve from a Jeep Cherokee.

A plunger style check valve was installed in 7 tanks, 6 of which did not leak from the filler tube when the filler cap was removed. The mechanism shown in Figure 1 (c) was not effective at retaining fluid with the filler cap removed. The mechanism shown in Figure 1 (a) was discovered in 5 tanks from 3 different automotive manufacturers and was effective at preventing leakage from the filler tube.

Fluid loss was encountered with the Saturn SL which used a check valve as shown in Figure 1 (a). However, the leak stemmed from the filler venting tube

and not from the filler tube check valve. Figure 4 shows the filler tube which is routed inside the vent tube arrangement.

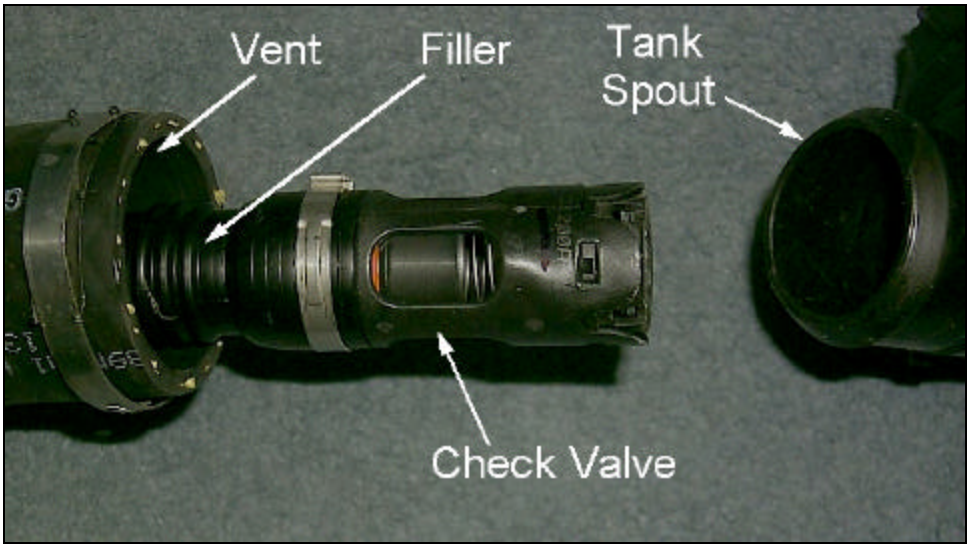


Figure 4: Saturn SL filler tube and vent tube arrangement.

Flap style check valves similar to those shown in Figure 2 were used in 7 fuel tanks. However, only the Kia Spectra flap valve seen in Figure 2 (c) was effective. All other flap valves permitted fluid loss. The difference between the Spectra flap valve design and other designs is that the Spectra valve enhanced the seal effectiveness by incorporating a rubber disc between the flap and the valve orifice. The other designs relied on steel to plastic or plastic to plastic parts sealing to prevent fuel from leaking. The rubber disk can be seen in the photograph shown Figure 2 (c).

Of all the check valves observed, the ball float type valve was the only system in which the state of the valve was normally open, meaning that the filler tube would only be sealed if the ball was engaged, by gravity, rising fluid levels relative to the tank filler spout, or the reverse flow of fluid. All of these circumstances would act to seat the ball in the filler tube opening to prevent reverse flow. In the single instance of its use, the valve shown was not effective in the rollover testing at preventing leakage or limiting the leakage rate to below 28 g per minute as specified in the FMVSS 301 standard.

The GMC Sierra employed a similar filler design to the Saturn in that the filler tube was routed inside a larger tube which acted as the tank filler vent. Unlike the Saturn, the Sierra did not incorporate a check valve on the end of the filler tube (see Figure 5). Instead, inside the tank the filler tube extended to the far side of the tank, therefore, depending on the tank orientation and fluid level the filler tube design may prevent fuel spillage. A cut-away view of the Sierra tank is shown in Figure 6.

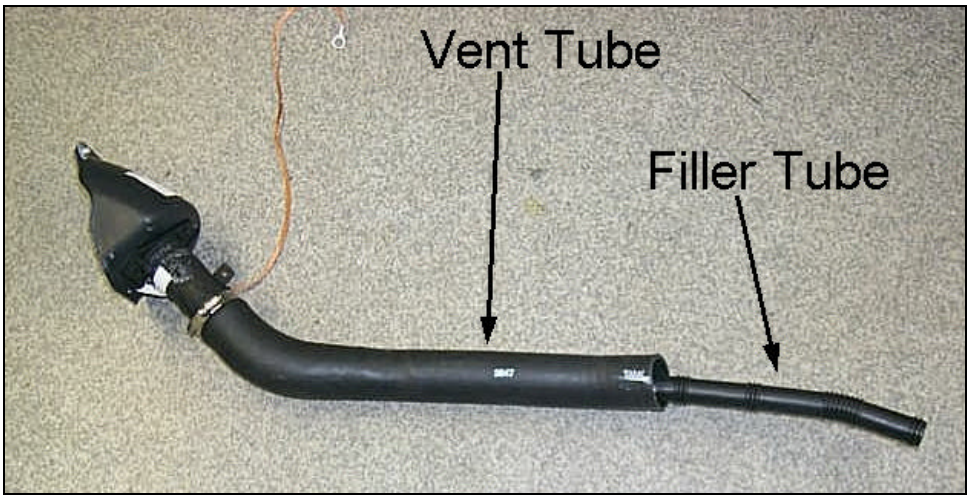


Figure 5: GMC Sierra vent and filler tube arrangement.

Figure 6: Cross-section of the upper half of a GMC Sierra gas tank.

3.2 Filler Check Valve – Tank Exterior

A flap valve in the filler tube just behind the gas cap was present in 12 fuel systems. The valves are physically opened by the fuel nozzle of the gas pump during refuelling. An additional 4 systems incorporated a flap valve in the filler tube closer to, but still exterior to, the tank. On these systems the fuel pressure is sufficient to open the valve during refuelling. These valves restricted flow yet

none were effective at preventing reverse flow of fluid out of the tank during the rollover leak testing. This suggests that their purpose may be for vapour entrapment for emissions reduction. A typical flap valve found in the filler tube behind the gas cap is shown in Figure 7. An example of a flap valve installed closer to the tank in the filler tube is shown in Figure 8. The use of these valves are identified in Appendix A.

Figure 7: Flap valve found immediately behind the gas cap.

Figure 8: A flap valve installed closer to the tank in the filler tube.

3.3 Rollover Valves

Vents on the top of the tank allow for pressure balancing either to prevent suction in the ullage when fuel is consumed during vehicle operation or conversely to prevent excessive vapour pressure build-up. In some cases the

pressure equalization may be controlled with diaphragm valves to maintain the ullage pressure at predefined design specification. These vents are normally connected to a vapour canister to ensure vehicle compliance with environmental emission requirements.

If no countermeasures were incorporated to prevent fuel leakage through the vent lines and hoses when a tank was inverted, as in a vehicle rollover, leakage would certainly occur. With mandatory compliance with the FMVSS 301 standard, which limits allowable fuel leakage following a crash, it is not surprising that all the tank systems inspected were fitted with rollover valves to prevent leakage. For most tanks these valves were installed directly on the tank, whereas in other systems the rollover valves were completely contained inside the tank. A third approach positioned the valves on secondary reservoirs which were remote from the main tank. For this approach to be effective in a collision the lines and hoses connecting the secondary tank to the main tank must remain intact otherwise leakage could occur. Examples of rollover valve installations are shown in Figure 9 to Figure 11. Depending on a tank's geometry multiple rollover valves are used vent possible vapour pockets.

Figure 9: Rollover valves mounted directly to the Kia Spectra tank.

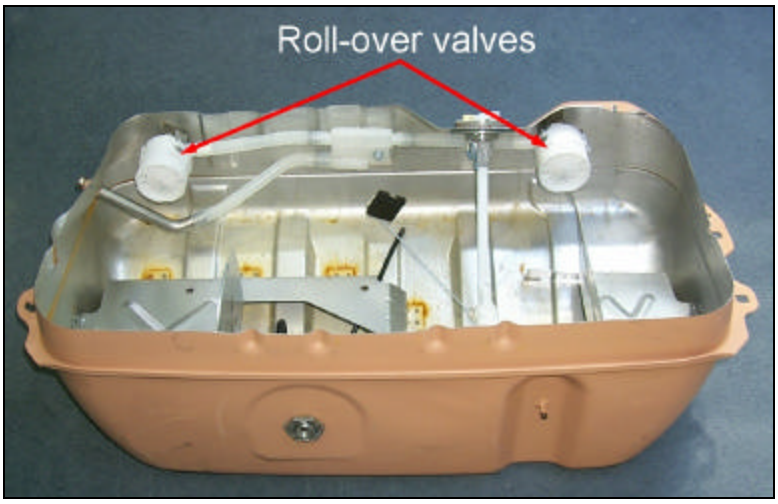


Figure 10: Rollover valves contained inside the Mercedes S430 tank.

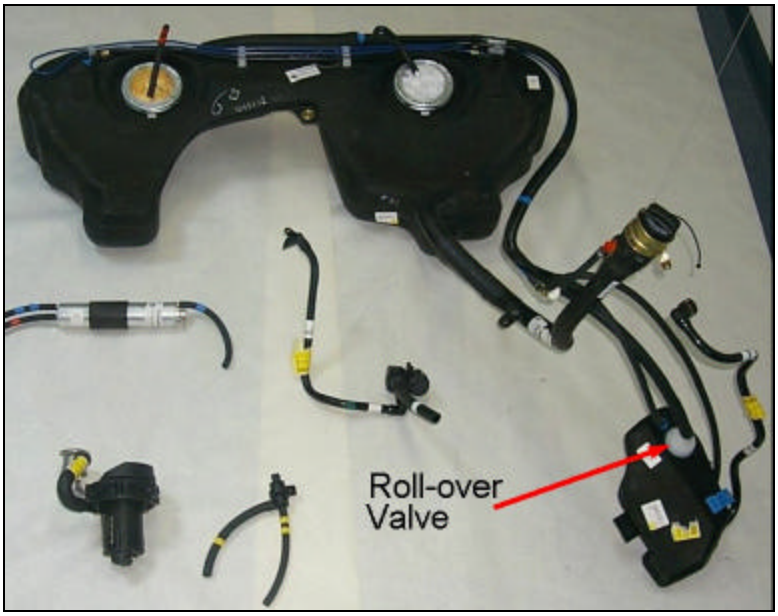


Figure 11: Rollover valve mounted on a secondary reservoir in the BMW 325 tank system.

Typically the rollover valves were normally opened, and under the influence of gravity and / or fluid flow the valves would seal. Springs or shifting ballast were two means by which the sensitivity of the valves to inversion was increased, thereby, decreasing the critical angle required to close the valves. When dry, the valves would engage as they approached approximately 70^{O} to 90^{O} rotation from their normal upright position. In many cases it was observed that friction prevented the valves from engaging in a repeatable manner. However, it is likely that lubrication provided by the gasoline would reduce the friction and

coupled with the buoyancy of the valve plunger and the flow pressure, would enable the valves to engage sooner. Many rollover valve designs were encountered, of which three are shown in Figure 12.

Figure 12: Examples of rollover valves from: a) Mercedes S430, b) Dodge Neon and c) Honda Odyssey.

The various rollover valve designs encountered all appeared to be effective at preventing fuel leakage when the tank was inverted. Nevertheless, for both the

Audi A8 and the BMW 325 tanks, excessive leakage was recorded at various inversion angles. Although the rollover valves for these vehicles appeared to function they were located on a secondary reservoir tank at a remote location to the main tank and it was the vent hoses leading to the secondary reservoir that leaked when severed. These vent hoses connected directly to the main tank without the benefit of a rollover valve.

4. Sending Unit Connections

Leakage during tank inversion was observed from the connections to the sending unit of 11 of the tanks systems tested. Depending on the fuel systems, these connections included the fuel delivery line to the engine and one or both of the following: the fuel return and / or the sender vent return.

Typically, the fuel pump is placed inside the tank, therefore, leakage from this line would suggest that the pump does not seal the delivery line to prevent leakage if the pump is not energized. Of the sending units that leaked, only one did not leak from the fuel delivery line. Additionally, the only tank system with the fuel pump located exterior to the tank leaked profusely from the fuel delivery line exiting the tank.

Of the 11 sending unit designs that leaked, 7 of them incorporated a fuel return line, each of which also leaked. Furthermore, the two sending units that included a sender vent return line leaked from that connection.

Examples of sending units with 1, 2 and 3 connections are shown in Figure 13.

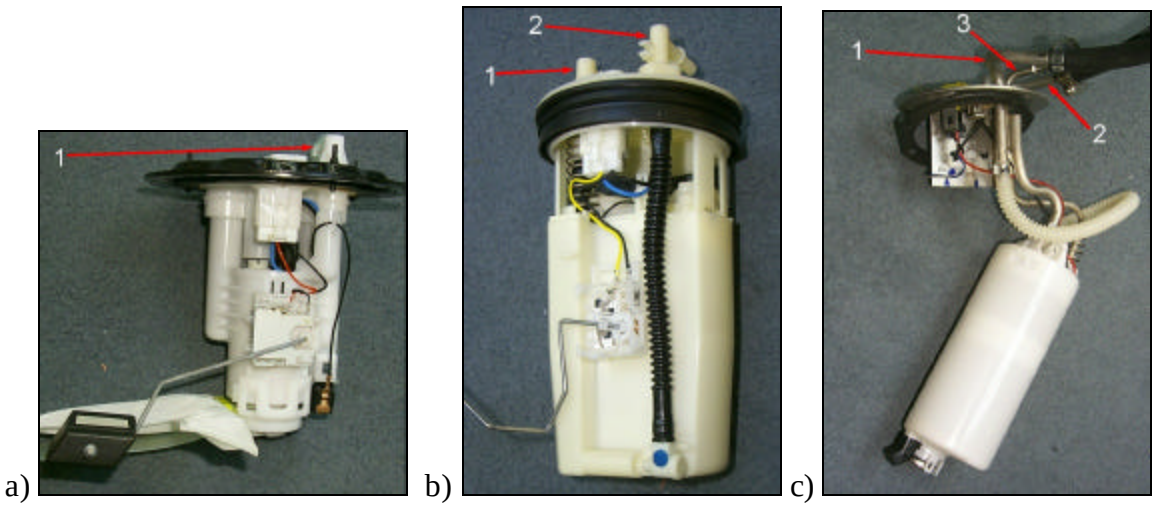


Figure 13: Sending units with 1, 2 or 3 fuel line connections from: a) Mazda MPV, b) Honda Odyssey and c) Chevrolet Corvette.

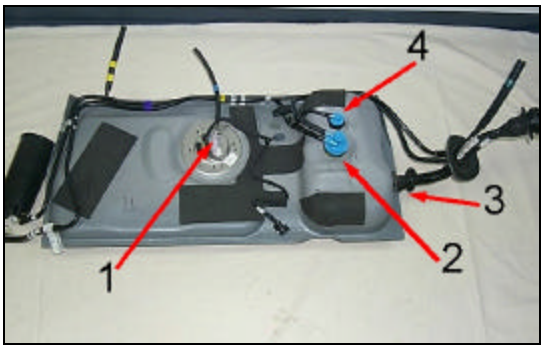
There were 9 sending units that did not leak when inverted and they comprised of either one or two fuel line connections but did not include a sender vent return line. With these sending units the pump would prevent fluid flow when not operational and the fuel return line was routed through a check valve or rollover type valve.

These designs demonstrate that with the proper pump design and selection of valve components that sending units can be made to prevent fuel leakage if the fuel lines and hoses connected to it are damaged or severed in a crash.

5. Overall Tank Design

Obviously, the crashworthiness of a gas tank and its installation is of significant importance to preventing post collision fuel leaks. If, however, the tank is undamaged and the fuel lines or hoses are damaged then the possibility of post crash fires occurring may still exist, unless the tank system is designed to prevent this leakage.

The ability to design such a tank was evident from the results of the leak testing on 4 of the tank systems summarized previously in Table 1. These tank systems proved that it was possible to design connections and fittings to the tank that would not leak if the lines and hoses connected to them were severed one at a time. Interestingly, the tanks were obtained from mid to low end vehicles, which suggests that a "spill" proof tank does not require advanced or expensive technology to be achieved. Additionally, in comparison to several other tanks evaluated in the test series, these tanks were of simple design with 4 or 5 lines and hoses connected to it, compared to other tanks systems which had from 6 to 11 fuel hose connections. Examples of hose connections to a tank are shown in Figure 14. It should be noted that there were tank systems with 4 to 5 hose connections that did leak. However, limiting the number of connections to a tank may reduce the opportunity for a fuel line or hose to be damaged in a collision, thereby relegating effective precautions to prevent spillage as failsafe for a crashworthy tank installation.

a) 

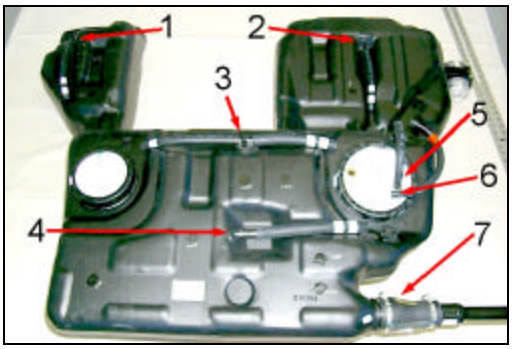
b) 

Figure 14: Tanks systems with, a) 4 hose connections; and with, b) 7 hose connections.

Ultimately, what is important for tank design considerations is that each line emanating from the main tank must have a spill prevention device such as a rollover valve or a check valve installed. The tanks that passed the leak test in all orientations complied with this principle. As an example of non-compliance with this principle, ten of the tanks inspected did not employ a rollover valve on the filler vent. Consequently, in these instances a severed line essentially equates to a hole directly into the tank which will leak if below the fluid level, as was observed in the testing.

6. Summary

Biokinetics conducted leak testing on 20 fuel tanks. The tanks were rotated in one direction to eight discreet positions and the fuel system hoses were disconnected one at a time to represent damaged or severed lines or hoses. The resulting leakage rates were observed. In summary the test results showed that:

- none of the tanks leaked if the lines and hoses were intact,
- 4 tanks did not leak in any orientation,
- 6 tanks leaked in every tank orientation.

Fifteen of the 20 tanks inspected had a filler check valve installed in the tank. Three style of valves including spring loaded plungers, flap door mechanisms and ball/float arrangements were identified. Generally, the spring loaded plungers were effective at preventing leakage while the others were not.

Flap valves installed exteriorly to the tank were present in 16 filler tube assemblies either in the filler tube just behind the gas cap or in the filler tube closer to the tank. These valves restricted flow but none prevented fluid from leaking out of the filler tube, suggesting that their purpose is for vapour entrapment for emissions reduction.

Likely as a consequence of the implementation of the FMVSS 301 standard, all tank systems evaluated employed a rollover valve on the tank vents employed for regulating the pressure in the ullage of the tank. Many rollover valve designs were encountered and if installed on or inside the tank all appeared to be effective at preventing fuel leakage when the tank was inverted. Although the valves themselves may have prevented fluid loss, if installed remotely from the main tank, leakage from the connection to the tank was still possible.

Leakage from the sending unit connections was observed in 11 of the tank systems tested. For the 9 sending units that did not leak, the pump would prevent fluid flow when not operational and the fuel return line was routed through a check valve or rollover type valve. These designs demonstrate that with the proper pump design and selection of valve components, that sending units can be made to prevent fuel leakage if the fuel lines and hoses connected to it are damaged or severed in a crash.

The results from 4 tanks that did not leak in any orientation demonstrated that it is possible to design connections and fittings to the tank that would not leak if the hoses connected to them were severed. Furthermore, the fact that these tanks were simply designed and came from mid to low end vehicles suggests that advanced or expensive technology is not required to achieve these results.

The results of the rollover leakage tests highlight the importance of incorporating leak prevention devices such as rollover valves and check valves in the tank for every line or hose emanating from the main tank. Fuel leakage prevention is a necessary requirement and must compliment the crashworthiness performance of vehicles to ensure that the risk of fuel fed fires is mitigated.

7. References

Ref. 1 Fournier, E., Kot, J., “Summary Report: Expansion of the Vehicle Fuel System Database and Overview of Pickup Truck History”, Biokinetics and Associated Ltd., Biokinetics report R04-02 v02, February 2004.

Ref. 2 Bedewi, P., “Make & Model Review of Fatal Analysis Reporting System (FARS) by Fire Occurrence In Fatal Crashes and Fatalities by Most Harmful Event as Fire”, Motor Vehicle Fire Research Institute, March 1, 2003.

Appendix A : Leak Testing Results

The leak testing comprised rotating a full tank about an axis that, for a tank installed in a vehicle, would be parallel to the longitudinal axis of the vehicle. For safety and environmental reasons, the tanks were filled with soapy water instead of gasoline or Stoddard. In each tank orientation the hoses connected to the tank were disconnected one at a time and the leakage rate was observed and measured. The results for the individual tanks are summarized in this Appendix. As a point of reference, the allowable leakage specified in FMVSS 301 is 28 grams per minute and in most cases the observed leaks were largely in excess of this amount.

Acura 3.2 TL

Position	Location					
	Tank Lines and Hoses Intact	Filler Neck Vent	Filler Cap Off	Fuel Supply	Fuel Return	Vent Lines
0	N	N	N	N	N	N
60	N	N	N	Y	Y	N
90	N	N	N	Y	Y	N
120	N	N	Y	N	Y	N
180	N	N	N	N	Y	N
210	N	N	N	N	Y	N
270	N	N	Y	Y	Y	N
300	N	N	N	N	N	N

Tank Rotation: Counter Clockwise
Filler Neck Position: Left Side
Check valve inside tank: Yes
Type of check valve: Flap mechanism
Flap valve behind gas cap: None
Rollover valve type: Spring loaded
Number of hose connections: 5

The leakage rate was measured in grams.

Notes:
- Rate of leakage with filler cap off was greatest at 270 degrees @ 415 grams per min.

- Fuel supply leak was greatest @ 60 degrees, at a rate of 130 grams per min.

- Fuel return leakage was constant, in excess of 500 grams per min.

Audi A8

Position	Location					
	Tank Lines and Hoses Intact	Filler Neck Vent	Filler Cap Off	Fuel Supply	Fuel Return	Vent Lines
0	N	Y	N	N	N	N
60	N	Y	Y	N	N	Y
90	N	Y	Y	N	N	Y
120	N	Y	Y	N	N	Y
180	N	Y	Y	N	N	Y
210	N	Y	N	N	N	Y
270	N	Y	N	N	N	Y
300	N	Y	N	N	N	Y

Tank Rotation: Clockwise
Filler Neck Position: Right Side
Check valve inside tank: No
Type of check valve: n.a.
Flap valve behind gas cap: Yes and a second flap was also located closed ot the tank.
Rollover valve type: Shifting ballast
Number of hose connections: 7

The leakage rate was measured in grams.

Notes:
- Filler neck contains several vent lines and a secondary tank in which fluid pools as tank is rotated, leakage occurs in excess of 1000 grams per minute at 60 degrees rotation.

- Filler neck vent lines at the tank leak in all positions in excess of 1000 grams per minute.

- Filler neck with cap off leaked from 60- 180 degree positions with flow in excess of 1000 grams per minute at the 180 degree position.

- Vent line leaked in excess of 1000 grams per min in almost all positions.

BMW 325i

Position	Location					
	Tank Lines and Hoses Intact	Filler Neck Vent	Filler Cap Off	Fuel Supply	Fuel Return	Vent Lines
0	N	N	N	N	N	N
60	N	N	N	N	N	N
90	N	N	N	N	N	N
120	N	N	N	N	N	N
180	N	Y	Y	N	N	Y
210	N	Y	Y	N	N	Y
270	N	Y	Y	N	N	Y
300	N	Y	Y	N	N	Y

Tank Rotation: Clockwise
Filler Neck Position: Right Side
Check valve inside tank: No
Type of check valve: n.a.
Flap valve behind gas cap: Yes and a second flap was also located closed ot the tank.
Rollover valve type: Shifting ballast
Number of hose connections: 6

The leakage rate was measured in grams.

Notes:
- Rate of leakage with filler cap off was greatest at 270 degrees in excess of 1000 grams per min.

- Filler neck vent line leaked at rate in excess of 300 grams per min at 270 degrees rotation.

- Vent lines at the tank were numbered individually, the blue vent line leaked at a constant rate of 430 grams per min at 180 degrees rotation and at a rate of 150 grams per min at 300 degrees.

- The largest diameter vent line leaked in excess of 1000 grams per min at 270 and 300 degrees of rotation.

- The third vent line leaked initially 230 grams before stopping at 180 degrees no other leakage occurred from this line except for the initial filling.

Chevrolet Corvette

				Black	Blue	Green	Black	Blue	
	Location								
Position	Tank Lines and Hoses Intact	Filler Neck Vent	Filler Cap Off	LS Fuel Supply	LS Fuel Return	LS Sender Vent	RS Fuel Supply	RS Return	Vent Lines
0	N	N	N	Y	N	Y	N	Y	N
60	N	N	N	Y	N	Y	N	Y	N
90	N	N	N	Y	N	Y	N	Y	N
120	N	N	N	Y	N	Y	N	Y	N
180	N	N	N	N	N	Y	N/A	N/A	N
210	N	N	N	Y	N	Y	N/A	N/A	N
270	N	N	N	Y	N	Y	N/A	N/A	N
300	N	N	N	Y	N	Y	Y	Y	N

Tank Rotation: Clockwise
Filler Neck Position: Left Side
Check valve inside tank: Yes
Type of check valve: Spring loaded plunger
Flap valve behind gas cap: Yes
Rollover valve type: Spring loaded
Number of hose connections: 12

The leakage rate was measured in grams.

Notes:
- Fuel system comprised a left and right fuel tank connected together with a 2 inch diameter hose.

- The system was not tested with the hose disconnected. With no restrictions at the hose ends leakage would have occurred from one or both tanks depending on the rotational position.

- Fuel supply lines leaked with the greatest leakage occurring in the zero position 25 grams per minute.

- Sender vent line was open with no restrictions. Leakage was constant. The greatest leakage occurred at zero degrees at a rate of 135 grams per minute.

- During rotation the right tank slipped breaking off a sensor, fluid leaked from this location in excess of 350 grams per minute at a rotation of 210 degrees.

Chrysler Cirrus

Position	Location					
	Tank Lines and Hoses Intact	Filler Neck Vent	Filler Cap Off	Fuel Supply	Fuel Return	Vent Lines
0	N	N	N	N	N/A	N
60	N	N	N	N	N/A	N
90	N	N	N	N	N/A	N
120	N	N	N	N	N/A	N
180	N	N	N	N	N/A	N
210	N	N	N	N	N/A	N
270	N	N	N	N	N/A	N
300	N	N	N	N	N/A	N

Tank Rotation: Counter Clockwise
Filler Neck Position: Left Side
Check valve inside tank: Yes
Type of check valve: Spring loaded plunger
Flap valve behind gas cap: Yes
Rollover valve type: Spring loaded
Number of hose connections: 5

The leakage rate was measured in grams.

Notes:
- Returnless system.

- There were no fuel leaks in any orientation,

Dodge Neon

Position	Location					
	Tank Lines and Hoses Intact	Filler Neck Vent	Filler Cap Off	Fuel Supply	Fuel Return	Vent Lines
0	N	N	N	N	N/A	N
60	N	N	N	N	N/A	N
90	N	N	N	N	N/A	N
120	N	N	N	N	N/A	N
180	N	N	N	N	N/A	N
210	N	N	N	N	N/A	N
270	N	N	N	N	N/A	N
300	N	N	N	N	N/A	N

Tank Rotation: Counter Clockwise
Filler Neck Position: Right Side
Check valve inside tank: Yes
Type of check valve: Spring loaded plunger
Flap valve behind gas cap: Yes
Rollover valve type: Spring loaded
Number of hose connections: 6

The leakage rate was measured in grams.

Notes:
- Returnless system.

- There were no fuel leaks in any orientation,

Ford Mustang

Position	Location					
	Tank Lines and Hoses Intact	Filler Neck Vent	Filler Cap Off	Fuel Supply	Fuel Return	Vent Lines
0	N	N	N	N	N/A	N
60	N	N	N	N	N/A	N
90	N	N	N	N	N/A	N
120	N	N	N	N	N/A	N
180	N	N	N	N	N/A	N
210	N	N	N	N	N/A	N
270	N	N	N	N	N/A	N
300	N	N	N	N	N/A	N

Tank Rotation: Clockwise
Filler Neck Position: Right Side
Check valve inside tank: Yes
Type of check valve: Spring loaded plunger
Flap valve behind gas cap: Yes
Rollover valve type: Spring loaded
Number of hose connections: 4

The leakage rate was measured in grams.

Notes:
- Returnless system.

- Initially the vent line on the tank leak 50 grams when the tank was filled to the top of the filler neck

GMC Serria

Position	Location						
	Tank Lines and Hoses Intact	Filler Neck Vent	Filler Cap Off	Fuel Supply	Fuel Return	Sender Vent	Vent Lines
0	N	N	N	N	N	N	N
60	N	N	N	Y	Y	Y	N
90	N	N	N	Y	Y	Y	N
120	N	N	N	Y	Y	Y	N
180	N	Y	Y	N	Y	N	N
210	N	Y	Y	N	N	N	N
270	N	Y	Y	N	N	N	N
300	N	Y	Y	N	N	N	N

Tank Rotation: Clockwise
Filler Neck Position: Left Side
Check valve inside tank: No
Type of check valve: n.a.
Flap valve behind gas cap: No
Rollover valve type: Spring loaded
Number of hose connections: 5

The leakage rate was measured in grams.

Notes:
- Rate of leakage with filler cap off was in excess of 1000 grams per min between 180 and 300 degrees rotation.

- The fuel supply and vent line leakage was minimal at less than 2 grams per minute.

- Fuel return leakage exceeded 1000 grams per min at 90 degrees rotation. At 180 degrees rotation, the flow rate dropped from 525 grams in the first minute to 93 grams per min in the fourth minute.

Honda Odyssey

Position	Location					
	Tank Lines and Hoses Intact	Filler Neck Vent	Filler Cap Off	Fuel Supply	Fuel Return	Vent Lines
0	N	N	N	N	N	N
60	N	N	N	Y	Y	N
90	N	N	N	Y	Y	N
120	N	N	N	Y	Y	N
180	N	N	Y	N	Y	N
210	N	N	Y	N	Y	N
270	N	N	Y	Y	Y	N
300	N	N	N	N	N	N

Tank Rotation: Counter Clockwise
Filler Neck Position: Left Side
Check valve inside tank: Yes
Type of check valve: Flap mechanism
Flap valve behind gas cap: No
Rollover valve type: Spring loaded
Number of hose connections: 7

The leakage rate was measured in grams.

Notes:
- Rate of leakage with the filler cap off was greatest at 270 degrees at 465 grams per min. At 180 degrees rotation the flow reduced from 175 grams in the first min to 33 grams per min after three minutes.

- Fuel supply leaked between 0 and 120 degrees and again at 270 degrees at a flow rate was in excess of 200 grams per min.

- Fuel return leakage was constant from 0-270 degrees with the greatest flow rate of 488 grams per min at 210 degrees rotation..

Jeep Cherokee

Position	Location					
	Tank Lines and Hoses Intact	Filler Neck Vent	Filler Cap Off	Fuel Supply	Fuel Return	Vent Lines
0	N	Y	N	N	N/A	N
60	N	N	N	N	N/A	N
90	N	N	N	N	N/A	N
120	N	Y	N	N	N/A	N
150	N	Y	Y	N	N/A	N
180	N	Y	N	N	N/A	N
210	N	Y	Y	N	N/A	N
270	N	Y	N	N	N/A	N
300	N	Y	Y	N	N/A	N

Tank Rotation: Counter Clockwise
Filler Neck Position: Left Side
Check valve inside tank: Yes
Type of check valve: Ball float
Flap valve behind gas cap: Yes
Rollover valve type: Spring loaded
Number of hose connections: 4

The leakage rate was measured in grams.

Notes:
- Returnless system.

- Filler neck vent line leaked from filler neck end with the cap on at 150, 210, and 300 degrees of rotation.

- Filler neck vent line at the tank end leaked in excess of 1000 grams per min in all positions except for 60 and 90 degrees.

- Rate of leakage with filler cap off was greatest at 210 degrees rotation at a rate in excess of 550 grams per min.

Kia Spectra

Position	Location					
	Tank Lines and Hoses Intact	Filler Neck Vent	Filler Cap Off	Fuel Supply	Fuel Return	Vent Lines
0	N	N	N	N	N	N
60	N	N	N	N	N	N
90	N	N	N	N	N	N
120	N	N	N	N	N	N
180	N	N	N	N	N	N
210	N	N	N	N	N	N
270	N	N	N	N	N	N
300	N	N	N	N	N	N

Tank Rotation: Counter Clockwise
Filler Neck Position: Left Side
Check valve inside tank: Yes
Type of check valve: Flap mechanism
Flap valve behind gas cap: Yes
Rollover valve type: Spring loaded
Number of hose connections: 6

The leakage rate was measured in grams.

Notes:
- There were no leaks.

Mazda MPV

Position	Location					
	Tank Lines and Hoses Intact	Filler Neck Vent	Filler Cap Off	Fuel Supply	Fuel Return	Vent Lines
0	N	Y	N	Y	N/A	N
60	N	Y	N	N	N/A	N
90	N	Y	N	N	N/A	N
120	N	Y	N	N	N/A	N
180	N	Y	Y	6 GRAMS	N/A	N
210	N	Y	Y	Y	N/A	N
270	N	Y	Y	Y	N/A	N
300	N	Y	Y	Y	N/A	N

Tank Rotation: Counter Clockwise
Filler Neck Position: Left Side
Check valve inside tank: No
Type of check valve: n.a.
Flap valve behind gas cap: None flap behind cap. Flab installed
Rollover valve type: Spring loaded
Number of hose connections: 4

The leakage rate was measured in grams.

Notes:
- Returnless system.

- Filler neck vent line at tank leaked constantly, flow rate was in excess of 400 grams per minute.

- Filler neck with cap off oriented at 80 degrees leaked at a rate of 81grams per min. At 270 degrees the flow rate increased to in excess of 600 grams per minute.

- Fuel supply line leakage was greatest at 210 degrees from 66 grams in the first minute to 23 grams per minute in the fourth minute. Leakage also occurred at 270 and 300 degrees. There was a minimal leakage of 6 grams total in the 180 degree position.

Mercury Grand Marquis

Position	Location					
	Tank Lines and Hoses Intact	Filler Neck Vent	Filler Cap Off	Fuel Supply	Fuel Return	Vent Lines
0	N	N	N	N	N	N
60	N	N	N	N	Y	N
90	N	N	N	N	Y	N
120	N	N	N	N	N	N
180	N	N	N	N	N	N
210	N	N	N	N	N	N
270	N	N	N	N	N	N
300	N	N	N	N	Y	N

Tank Rotation: Counter Clockwise
Filler Neck Position: Left Side
Check valve inside tank: Yes
Type of check valve: Spring loaded plunger
Flap valve behind gas cap: Yes
Rollover valve type: Spring loaded
Number of hose connections: 5

The leakage rate was measured in grams.

Notes:
- Leakage occurred at a rate of 35 grams per min in the 90 degrees position. The highest rate of leakage occurred at 300 degrees rotation at a rate of 69 grams per min.

- Leakage stopped between 100 and 280 degrees rotation.

Plymouth Grand Voyageur

Position	Location					
	Tank Lines and Hoses Intact	Filler Neck Vent	Filler Cap Off	Fuel Supply	Fuel Return	Vent Lines
0	N	N	N	N	N	N
60	N	Y	N	N	N	N
90	N	Y	N	N	N	N
120	N	Y	N	N	N	N
180	N	Y	Y	N	N	N
210	N	Y	Y	N	N	N
270	N	Y	Y	N	N	N
300	N	Y	N	N	N	N

Tank Rotation: Counter Clockwise
Filler Neck Position: Left Side
Check valve inside tank: No
Type of check valve: n.a.
Flap valve behind gas cap: Yes
Rollover valve type: Spring loaded
Number of hose connections: 7

The leakage rate was measured in grams.

Notes:
- Filler neck vent line at the tank end leaked in excess of 250 grams per min between 60 - 300 degrees rotation. Leakage occurred from filler neck end between 120 - 270 degrees at flow rate estimated to be above 150 grams per min.

- Rate of leakage with filler cap off was greatest at 180 degrees at a flow rate in excess of 1000 grams per min.

Toyota Camry

Position	Location					
	Tank Lines and Hoses Intact	Filler Neck Vent	Filler Cap Off	Fuel Supply	Fuel Return	Vent Lines
0	N	Y	N	N	N/A	N
60	N	Y	N	Y	N/A	N
90	N	Y	N	Y	N/A	N
120	N	Y	N	Y	N/A	N
180	N	Y	Y	Y	N/A	N
210	N	Y	N	Y	N/A	N
270	N	N	N	Y	N/A	N
300	N	N	N	Y	N/A	N

Tank Rotation: Clockwise
Filler Neck Position: Left Side
Check valve inside tank: Yes
Type of check valve: Flap mechanism
Flap valve behind gas cap: No
Rollover valve type: Spring loaded
Number of hose connections: 8

The leakage rate was measured in grams.

Notes:
- Returnless system.

- Filler neck vent lines at the tank leaked in excess of 400 grams per minute in all positions indicated.

- Filler neck with the cap off leaked at a rate of 73 grams per min. at the 180 degree orientation.

- Fuel supply line leakage was greatest at 120 degrees from 160 grams in the first minute to 135 grams per minute after three minute. Leakage also occurred at 0 degrees during the filling process if the tank was filled to the top of the filler neck.

Toyota Corolla

Position	Location					
	Tank Lines and Hoses Intact	Filler Neck Vent	Filler Cap Off	Fuel Supply	Fuel Return	Vent Lines
0	N	Y	N	N	N/A	N
60	N	Y	N	Y	N/A	N
90	N	Y	N	Y	N/A	N
120	N	Y	N	Y	N/A	N
180	N	Y	N	Y	N/A	N
210	N	Y	Y	Y	N/A	N
270	N	Y	N	Y	N/A	N
300	N	Y	N	Y	N/A	N

Tank Rotation: Clockwise
Filler Neck Position: Left Side
Check valve inside tank: Yes
Type of check valve: Flap mechanism
Flap valve behind gas cap: No
Rollover valve type: Spring loaded
Number of hose connections: 7

The leakage rate was measured in grams.

Notes:
- Returnless system.

- Filler Neck Vent leaked when disconnected from filler neck, draining fluid in filler neck.

- Fuel Supply leaked during over filling, as tank rotation approached 180 degrees flow rate increased exceeding 155 grams per min.

- Filler neck did not leak in the 180 position, however it did leaked as indicated at 120 degrees from horizontal where the filler neck is in an upside down position.

- Filler neck vent lines at the tank leaked 145 grams then stopped when all other lines were connected, movement of the tank caused further leakage spilling approx the 145 grams. with all lines disconnected the larger of the two vent lines at the filler neck opening leaked rapidly and constantly in excess of 450 grams per min.

Toyota Prius

Position	Location					
	Tank Lines and Hoses Intact	Filler Neck Vent	Filler Cap Off	Fuel Supply	Fuel Return	Vent Lines
0	N	N	N	N	N/A	N
60	N	N	N	Y	N/A	N
90	N	N	N	Y	N/A	N
120	N	N	N	Y	N/A	N
180	N	N	Y	Y	N/A	N
210	N	N	Y	Y	N/A	N
270	N	N	N	Y	N/A	N
300	N	N	N	Y	N/A	N

Tank Rotation: Clockwise
Filler Neck Position: Right Side
Check valve inside tank: Yes
Type of check valve: Flap mechanism
Flap valve behind gas cap: No
Rollover valve type: Spring loaded
Number of hose connections: 5

The leakage rate was measured in grams.

Notes:
- Returnless system.

- Filler neck with cap off leaked at a rate of 287 grams per minute over a three minute period in the 180 degree orientation.

- Fuel supply line leakage was greatest at 120 degrees with 185 grams per minute. Leakage at 90 to 180 degrees was similar at 173 and 165 grams per minute. Leakage at 300 degrees was less than 5 grams per minute.

VW Jetta

Position	Location					
	Tank Lines and Hoses Intact	Filler Neck Vent	Filler Cap Off	Fuel Supply	Fuel Return	Vent Lines
0	N	N	N	N	N	N
60	N	Y	N	N	N	N
90	N	Y	N	N	N	N
120	N	Y	N	N	N	N
180	N	Y	Y	N	N	N
210	N	Y	Y	N	N	N
270	N	Y	Y	N	N	N
300	N	Y	Y	N	N	N

Tank Rotation: Clockwise
Filler Neck Position: Right Side
Check valve inside tank: Yes
Type of check valve: Spring loaded plunger
Flap valve behind gas cap: Yes
Rollover valve type: Shifting ballast
Number of hose connections: 6

The leakage rate was measured in grams.

Notes:
- Filler neck vent line at the tank end leaks at rate of 730 grams per min in the 90-270 degree positions. Rate of leakage in the 60 and 300 degrees was lower.

- Rate of leakage with filler cap off was greatest at 180 degrees, with a flow rate of 704 grams per min.

Mercedes S430

Position	Location					
	Tank Lines and Hoses Intact	Filler Neck Vent	Filler Cap Off	Fuel Supply	Fuel Return	Vent Lines
0	N	N/A	N	Y	Y	N
60	N	N/A	N	Y	Y	N
90	N	N/A	N	Y	Y	N
120	N	N/A	N	Y	N	N
180	N	N/A	Y	N	N	N
210	N	N/A	Y	Y	N	N
270	N	N/A	Y	Y	N	N
300	N	N/A	Y	Y	N	N

Tank Rotation: Clockwise
Filler Neck Position: Right Side
Check valve inside tank: Yes
Type of check valve: Flap mechanism
Flap valve behind gas cap: Yes and a second flap was also located closed ot the tank.
Rollover valve type: Shifting ballast
Number of hose connections: 4

The leakage rate was measured in grams.

Notes:
- Filler neck with cap off leaked 245 grams in the first minute, 38 grams in the second and zero in the third minute at 180 degrees. At 240 degrees rotation 4830 grams were measured over a 5 minute period. Excessive leakage also occurred at 270 and 300 degrees.

- Fuel supply leakage was not measured. With the fuel pump located out side of the tank, leakage at this point through the fuel strainer was estimated in excess of 1000 grams per minute.

- Fuel return line leakage was greatest at 0 degrees with 217 grams per minute leakage. Leakage also occurred at 60 and 90 degrees.

Saturn SL

Position	Location					
	Tank Lines and Hoses Intact	Filler Neck Vent	Filler Cap Off	Fuel Supply	Fuel Return	Vent Lines
0	N	N	N	N	N	N
60	N	N	N	N	N	N
90	N	N	N	N	N	N
120	N	N	N	N	N	N
180	N	Y	Y	N	Y	N
210	N	Y	Y	N	Y	N
270	N	Y	Y	N	Y	N
300	N	Y	Y	N	N	N

Tank Rotation: Counter Clockwise
Filler Neck Position: Left Side
Check valve inside tank: Yes
Type of check valve: Spring loaded plunger
Flap valve behind gas cap: Yes
Rollover valve type: Spring loaded
Number of hose connections: 5

The leakage rate was measured in grams.

Notes:
- Rate of leakage with filler cap off was greatest at 270 degrees with 632 grams per min, at 300 degrees the flow reduced to 582 grams per min and at 180 degrees it reduced to 485 grams per min.

- Fuel return leakage was greatest at 210 degrees with a constant flow of 345 grams per min. Flow rates in other positions in which leakage occurred was constant.

DP09-005

MEMO 1-20-2010

JEEP GRAND CHEROKEE VULNERABLE FUEL HOSE & LINE

ZJ_FFH-1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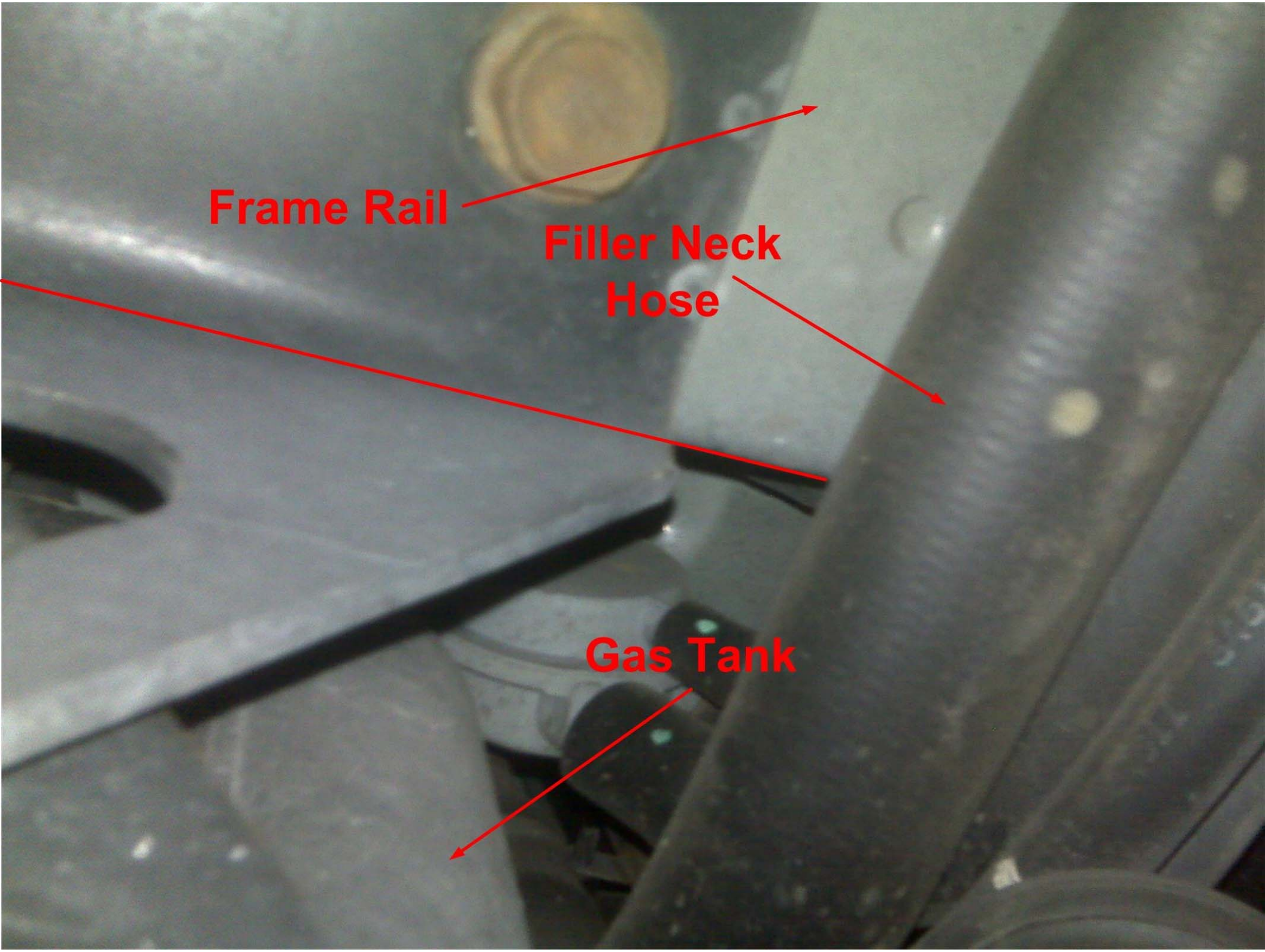
52018801
F 005
0862378-14

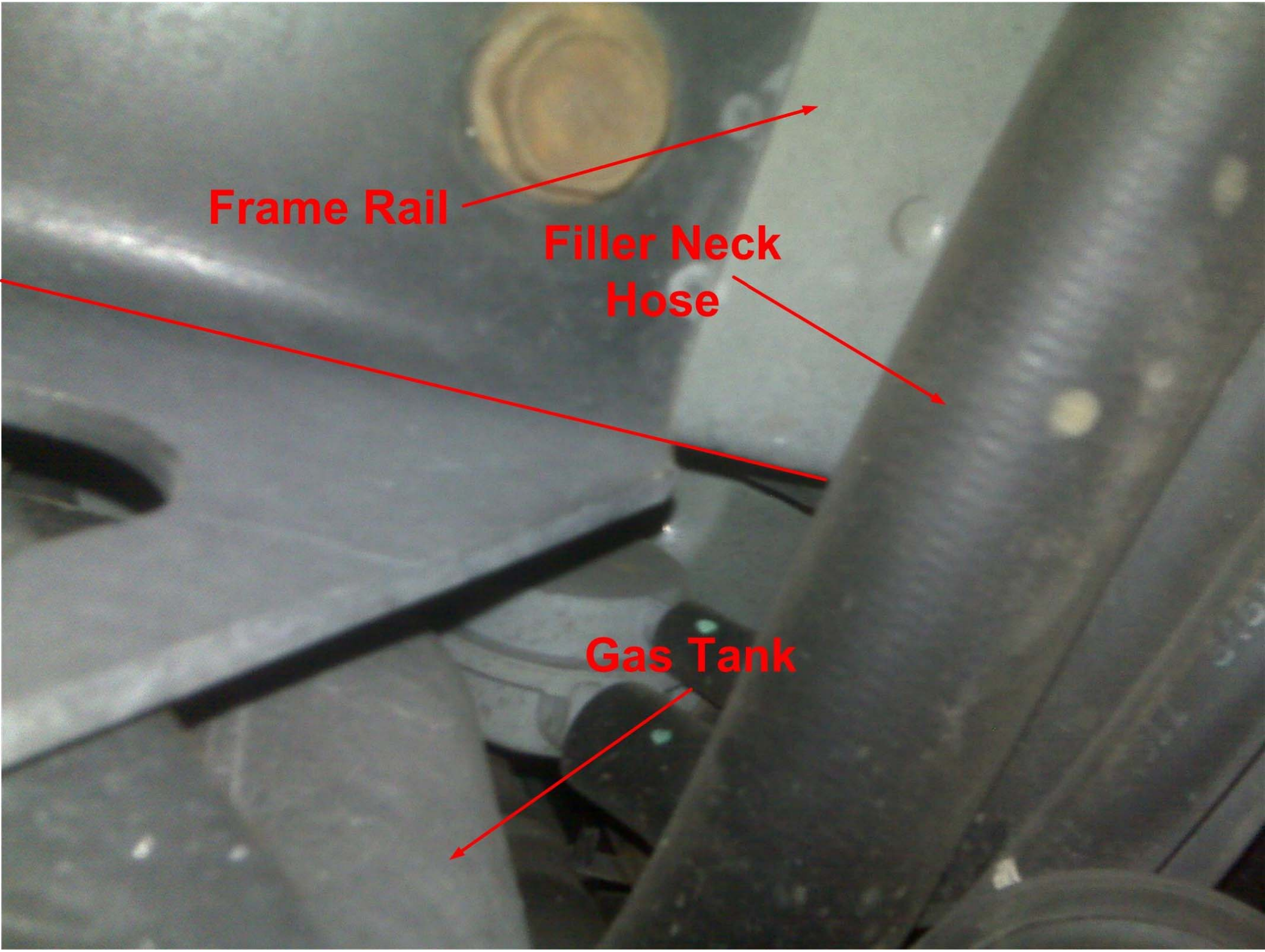

Frame Rail
Filler Neck
Hose
Gas Tank

DP09-005

MEMO 1-20-2010

JEEP GRAND CHEROKEE VULNERABLE FUEL HOSE & LINE

2004 Jeep Grand Cherokee Fuel Hose Under Frame Rail

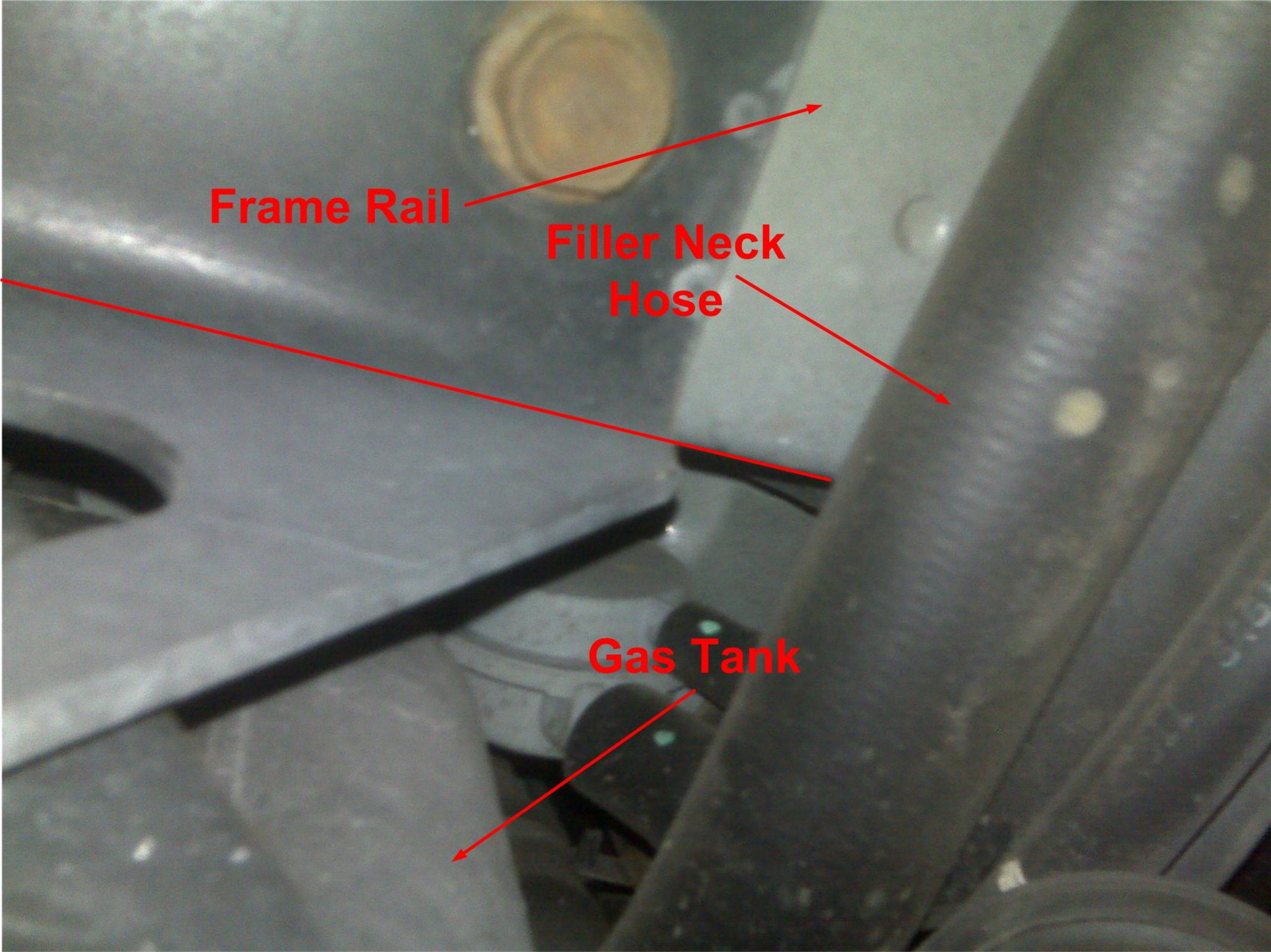

Frame Rail
Filler Neck
Hose
Gas Tank

DP09-005

MEMO 1-20-2010

JEEP GRAND CHEROKEE VULNERABLE FUEL HOSE & LINE

PHOTO


Frame Rail
Filler Neck
Hose
Gas Tank

PICK

9642-8687 2010-01-12-18.11.05

Loc: LBX1668B1

PDSRTE7-7-41

DLRDAILY F 005

52018801

Wgt: 0.93 / 0.93 lb

Qty: 1

Order: 0112DS
(SPORD)

11488C00V
HOSE

DOC 0862378-14


FUEL - 1 1/4 x 1 1/2 IN.
FUEL
PICK
Loc: LBX1668B1
DDSRTE7-7-41
52018801
DLRDAILY F 005
HOSE
0862378-14
Ord: 1
Order: DU1ZDS
(SPORD)
(81796000)

1993 – 1998 Jeep Grand Cherokee
ZJ-Body

Fuel Filler Hose
(rubber w/nylon mesh jacket)

Through Frame Rail Routing

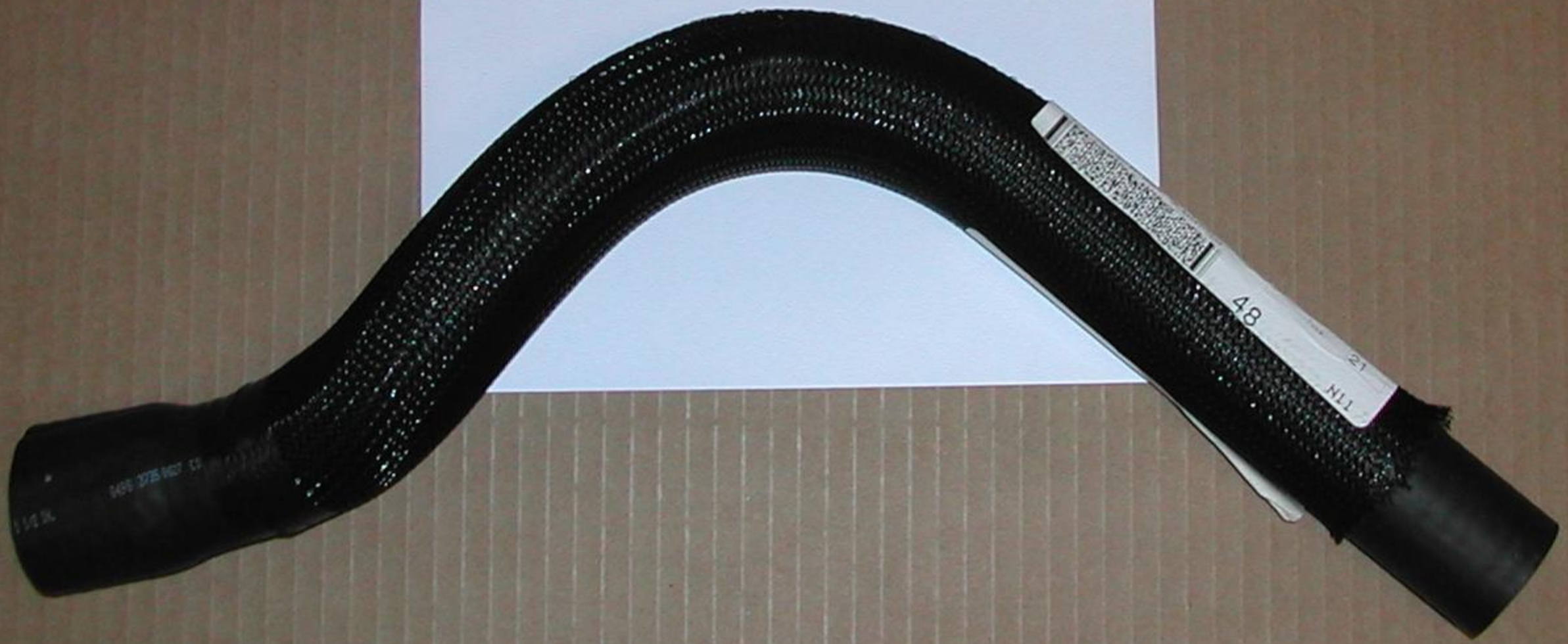
MOPAR Service Part
50218801

1993 – 1998 Jeep Grand Cherokee
ZJ-Body

Fuel Filler Hose
(rubber w/nylon mesh jacket)

<u>Through</u> Frame Rail Routing

MOPAR Service Part
50218801



1993 – 1998 Jeep Grand Cherokee
ZJ-Body

Fuel Filler Hose
(rubber w/nylon mesh jacket)

Through Frame Rail Routing

MOPAR Service Part
50218801

MOPAR Service Part
50218801