**MVFRI RESEARCH SUMMARY**
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# Test and Evaluation of the State-Of-The-Art in Fuel Leakage Prevention

Based on contracts with:
Biokinetics and Associates, Ltd.

MVFRI contracted with Biokinetics and Associates Ltd to conduct tests and evaluations of fire safety features in on-the-road vehicles. Two types of evaluations were done. First, the leakage prevention technology was evaluated through component testing of fuel systems in rollovers with severed fuel and vent lines. Second, tests were undertaken to evaluate and document anti-siphoning technology. The technologies that prevented siphoning and leakage from severed fuel and vent lines was documented with photographs and descriptions.

## TECHNOLOGY FOR FUEL CONTAINMENT IN ROLLOVER

Biokinetics conducted rollover leakage tests on 20 fuel tanks to study the fuel containment technologies employed and the performance of alternative technologies. The tests simulated a vehicle rollover by rotating a tank, filled to capacity. The rotation was 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 is 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. Liquid soap was added to the water to reduce surface tension and promote capillary flow as much as possible.

The tanks were rotated to seven 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 were varied with some tanks leaking in every orientation and others not leaking at all [Fournier, May 2004].

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.

In summary the test results showed that:

- None of the tanks leaked if the fuel hoses were intact,
- Four (4) tanks did not leak in any orientation,
- Six (6) tanks leaked in every tank orientation.

Fifteen of the 20 tanks inspected had a filler check valve installed in the tank. Three styles of valves are used: spring-loaded plungers, flap door mechanisms, and a ball/float arrangement. Generally, the spring loaded plungers were more effective at preventing leakage.

Flap valves installed exterior 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 vapor 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. This vent regulates 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 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 when the hoses connected to them are 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 state-of-the art capability of incorporating leak prevention devices such as rollover valves and check valves in the tank for every fuel line and hose emanating from the main tank.

After testing, the fuel tanks were cut apart and the components and designs that prevented fuel leakage were documented. The leakage results for each of the 20 tanks in each test condition and pictures of leakage prevention components were documented in a final report [Fournier, July 2004].

**TECHNOLOGY FOR FUEL CONTAINMENT BY ANTISIPHONING TECHNOLOGY**

For siphoning to occur, the line must be primed (contain fuel), it must pass through a point that is above the surface of the fuel in the tank and the exit point must lie below the fuel surface (designated by the dimension “h” in Case #2 of Figure 1 and referred to as the “head”) [Fournier, 2006]. A vacuum created by the flow of fuel from the discharge point draws liquid from the tank. Fuel flow will continue until the fuel level in the tank reaches the level of the discharge point or if, in an otherwise sealed tank, the vacuum created in the ullage matches that of the siphon. The tank components’ resistance to siphoning was evaluated by applying a vacuum with a vacuum pump to the tank port connections.

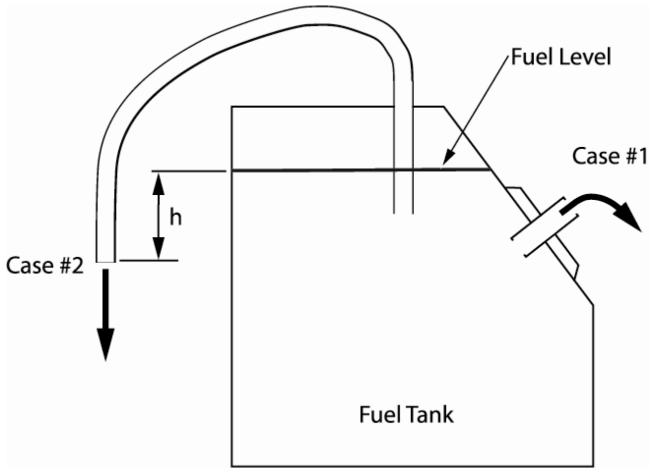


**Figure 1: Leakage and siphoning diagram**

An additional test was conducted to establish a relationship between the flow rate of a liquid with a fixed head and the measured vacuum pressures. The test apparatus consisted of a flexible tube with a ball valve installed mid length. With the valve set to different closure levels the vacuum pressure created by tube was measured. For each valve setting the tube and valve assembly was primed and one end was placed in a tank of water. The other end of the tube was placed in a graduated cylinder at a fixed distance below the surface level of the water in the tank. The volume of flow that occurred in one minute was measured.

In these tests, air, not fuel was drawn through the components. However, if the air is replaced by a fluid, the fluid's surface tension and viscosity may prevent siphoning at less than the full vacuum being measured. Additionally, the placement of a valve or fuel line termination within a tank may prevent siphoning from occurring regardless of measured vacuum. For example, if a normally open valve is located at the top of the tank, above the surface of the fuel, siphoning would not occur in the upright orientation despite the fact that a vacuum can not be generated.

Of the tank systems inspected only one was found to generate a full vacuum on the fuel delivery line. Eight of the fifteen sending units that included a fuel return line generated a full vacuum on that line, whereas, none of the four sending units with a vapor return line generated a full vacuum on the return line.

In principle, those sending unit lines that did not generate a full vacuum in the tests are susceptible to siphoning, with the flow rate varying depending on the resistance that is present in the lines. However, if a mechanical resistance exists that requires a minimum vacuum to be generated before flow can commence, less than perfect vacuum measurements on a line may be sufficient to prevent siphoning. Additionally, the placement of an exit point or valve within a tank may prevent siphoning regardless of the ability to generate a vacuum in the test conducted. Exit points or valves located at the top of a tank would prevent siphoning in an upright orientation. Without a valve, it is conceivable that a tank's orientation other than the upright position would permit siphoning.

The qualities of a tank system that have been found, through leak testing and siphon testing, to be effective at preventing fuel loss either from leakage or siphoning are listed below and depicted in Figure 2.

1. Effective, normally closed check valve located on the filler tube.
2. Rollover valves on all vapor ports.
3. Vapor port exit points inside the tank located at the top of the tank.
4. A returnless sending unit with a spring loaded check valve in the fuel delivery line.
5. Check valve or anti-siphon valve located inside the tank, at the top for the fuel return line and fuel vapor return line (if present).

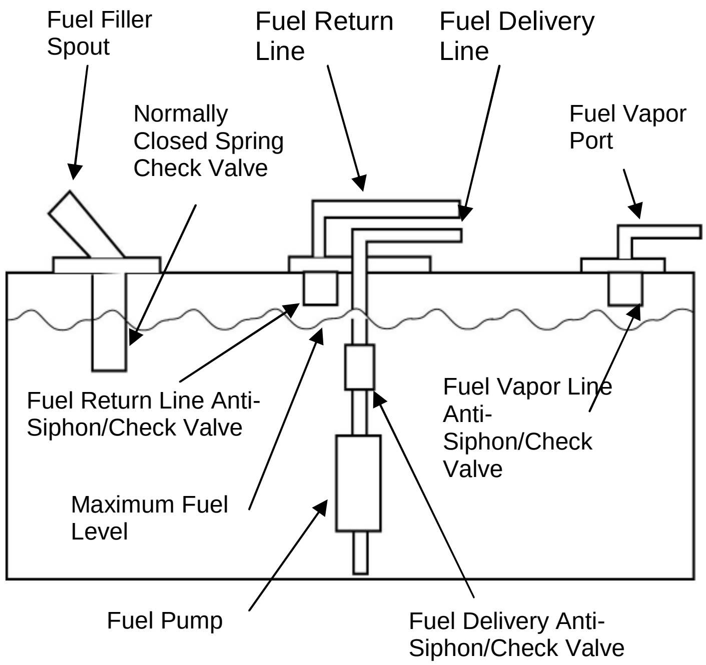


**Figure 2: Ideal fuel tank component features.**

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