

**GASOLINE VAPOR BEHAVIOR  
DURING LEAK DETECTION ACTIVITIES  
ON A MOTOR VEHICLE**

January 17, 2005

**Combustion & Environment Research Group**

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**1.0 PREAMBLE**

Vehicle fuel systems use seals, vapor lines, charcoal canisters and various valves as part of an evaporative emission control system to prevent atmospheric emission of fuel vapor. Any leaks in the fuel tank vapor space or evaporative emission control system can compromise emission control. Hence, it is a routine service procedure to detect and locate "evap system" leaks. Generally, leak detection systems either evacuate or pressurize the vehicle fuel system in the leak finding process. This can displace significant quantities of fuel vapor and may lead to flash fire and explosion hazards in the service facility. The hazard level depends on the quantity and concentration of vapor released during testing and this can depend on a number of factors ranging from how the testing is conducted to the fuel properties and ambient conditions. It is common to estimate a number of parameters, leading to some uncertainty in the accuracy of the hazard analysis. This report describes some experiments and calculations developed to quantify the behavior of fuel vapor during typical leak detection and leak finding activities.

## **2.0 INTRODUCTION**

The hazard inside a vehicle's fuel tank vapor space and evap system relates to the quantity of fuel vapor / air mixture that is in the flammable range. Gasoline fuel is designed to have a vapor pressure sufficiently high that the vapor concentration in a closed vessel is always above the upper flammable limit. However, leak detection systems may force some flow through the fuel tank vapor space and purge this too-rich-to-burn mixture out of the tank. As this happens, the vapor concentration will drop towards a lower value. This lower concentration is determined by the rate of flow through the system and the rate of gasoline evaporation at the liquid surface. If air is used as the driving gas for the leak detection process, (or if the leak detection equipment draws a vacuum which pulls atmospheric air into the tank vapor space), there will be some ratio of air flow rate relative to gasoline evaporation rate that generates a significant amount of flammable mixture. The rate of gasoline evaporation in a fuel tank during purge flows similar to those used in leak detection is uncertain and this leads to uncertainty in the maximum safe flows for leak detection equipment.

The hazard outside a vehicle's fuel system during leak detection activities arises from tank vapor space contents being emitted into the air: 1) through leaks, 2) through deliberate openings such as an open fuel cap used while filling the evap system with "smoke", 3) through the evaporative emission control charcoal canister, and 4) through the leak testing machine if it is pulling a vacuum on the evap system. The generally fuel-rich vapor / air mixture drawn out of the tank vapor space needs to be diluted with a sufficient quantity of air to ensure it is below the lower flammable limit. It is common to assume a high vapor concentration at the start of testing when the fuel tank is likely to be close to an equilibrium vapor pressure. However, with testing time, the vapor concentration of flow out of the system is expected to drop to a lower value, again determined by the rate of fuel evaporation relative to the rate of flow imposed by the leak detection equipment. The flash fire hazard external to the vehicle systems depends on the exiting vapor concentration, on the rate of vapor emission relative to external mixing and dilution, as well as on the cumulative amount of vapor emission in the event that external mixing and dilution is not adequate. All of these factors are affected by the gasoline evaporation rate in the fuel system.

In addition, the charcoal canister can significantly affect the vapor emission rate if the exit flow is through the canister. The canister is generally assumed to absorb hydrocarbon vapors completely until it reaches breakthrough and methods for measuring the breakthrough hydrocarbon mass are fairly well established. However, there is some uncertainty about: 1) whether older canisters, (from the vehicle models before on-board refuelling vapor recovery), are able to absorb all the hydrocarbon at relatively high flow rates, and 2) the fraction of hydrocarbon vapors that passes through the canister once it has filled to its breakthrough point.

Hence, the questions to be answered by this research project are:

1. For leak detection air flow blowing through the fuel tank vapor space:
  - a. What is the initial hydrocarbon concentration in the tank vapor space?
  - b. What is the evaporation rate in the tank once vapor starts to flow out of it?
  - c. How does evaporation rate change with fuel volatility, (Reid Vapor Pressure)?
  - d. Does the evaporation rate change with air flow rate through the tank?
  - e. How do initial hydrocarbon concentration and fuel evaporation rate affect the flammability of the mixture inside and exiting the tank during leak detection activities?
  
2. For leak detection air flow blowing through the fuel tank and out the canister:
  - a. How much hydrocarbon vapor passes through a canister once it starts to break through?
  - b. Is the vapor concentration exiting the canister still flammable?
  - c. How is that affected by how much air is flowing through the system?
  - d. What about the flammability of the mixture inside the fuel tank during this process?

### **3.0 EXPERIMENTAL METHODS**

The experiments developed to test fuel evaporation rate and actual emission rate involved forcing measured air flow rates through a vehicle evap system and fuel system which contained fuel of a known temperature and RVP. The rate of hydrocarbon vapor emission at known exit points was measured by absorbing it in a continuously weighed charcoal canister which was monitored to determine whether any hydrocarbon breakthrough occurred.

The test vehicle was a 1997 Chevrolet Cavalier with approximately  $\frac{1}{2}$  fuel level of 10.5 psi RVP gasoline in its 50 Liter tank. A lab air supply was connected through a mass flow meter to either the evap system service port or a gas filler cap with an added hose connection. The tank and evap system was sealed except for one exit point which was connected to an evap emissions system charcoal canister on a sensitive scale. The canister absorbed any hydrocarbon vapors in the tank exit flow and a flame ionization detector was used to detect any hydrocarbon vapors leaving the canister, thus indicating whether the canister had reached hydrocarbon breakthrough.

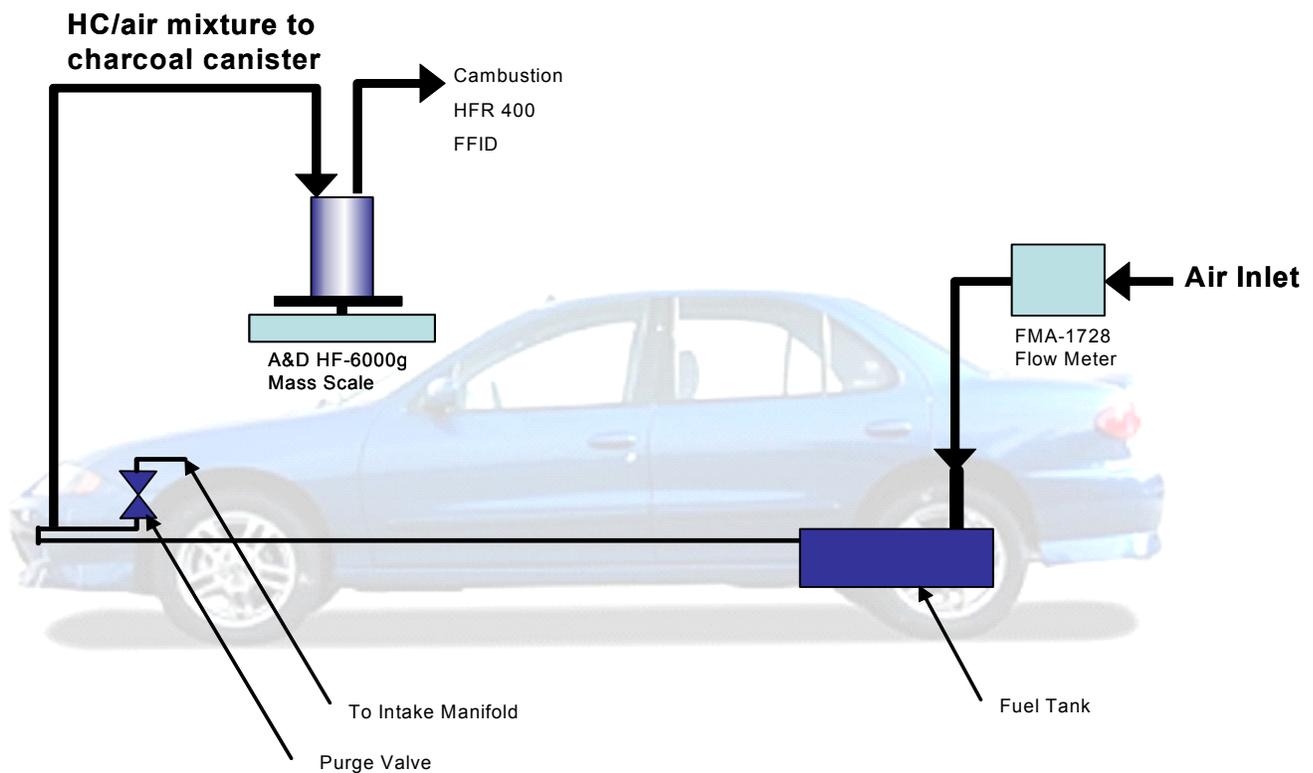
To extend these tests to a range of gasoline volatilities, further tests were done with a same-model fuel tank assembly complete with filler neck, fuel pump assembly and standard evap emission system connections. This tank was connected to lines and a canister simulating the normal vehicle evap emission control system. However, it could be easily emptied and re-charged with gasoline samples blended to provide a range of fuel volatility.

Figure 1 shows a typical experimental setup with the whole vehicle. The air supply flow was measured with an OMEGA FMA-1728 mass flow meter which provided a 0-5V output monitored by a PC data acquisition system. The charcoal canister was a previously characterized canister of the same type used on the 1997 Cavalier model. The scale was a HF-6000g unit with serial output which was read by the PC data acquisition system to continuously monitor the mass gain of the canister. The FID was a Cambustion HFR-400 unit with a response time measured in milli-seconds. For all the conditions tested, the hydrocarbon concentration exiting the canister remained at zero until the canister reached breakthrough and then rose abruptly to a point which was off-scale for the FID at the calibration being used.

Atmospheric pressure and temperature at the time of testing were 92 kPa and 22°C, respectively and the vehicle and its fuel had remained in the temperature-controlled lab for more than 24 hours to equilibrate. Air flow rates of 11  $\ell$ /min, 15  $\ell$ /min, and 20  $\ell$ /min were used to determine the effect of normal to higher-than normal air flow on gasoline evaporation rate. The

objective was to deliberately work into the range where air flow was sufficient to produce a highly flammable mixture in the vehicle fuel system.

When detecting leaks, connections to the evaporative emissions system are generally made at one of two locations: the evap system service port or the gas filler cap. If a service port is available, as is common in OBD-II vehicles, it is generally used. However many vehicles produced in the past, particularly pre-OBD-II vehicles, do not have a service port. In this case, the gas filler cap is removed and replaced with a cap that has a fitting installed for an external port. Tests were run with two different test scenarios to represent connection to either the evap system service port or the gas filler cap.



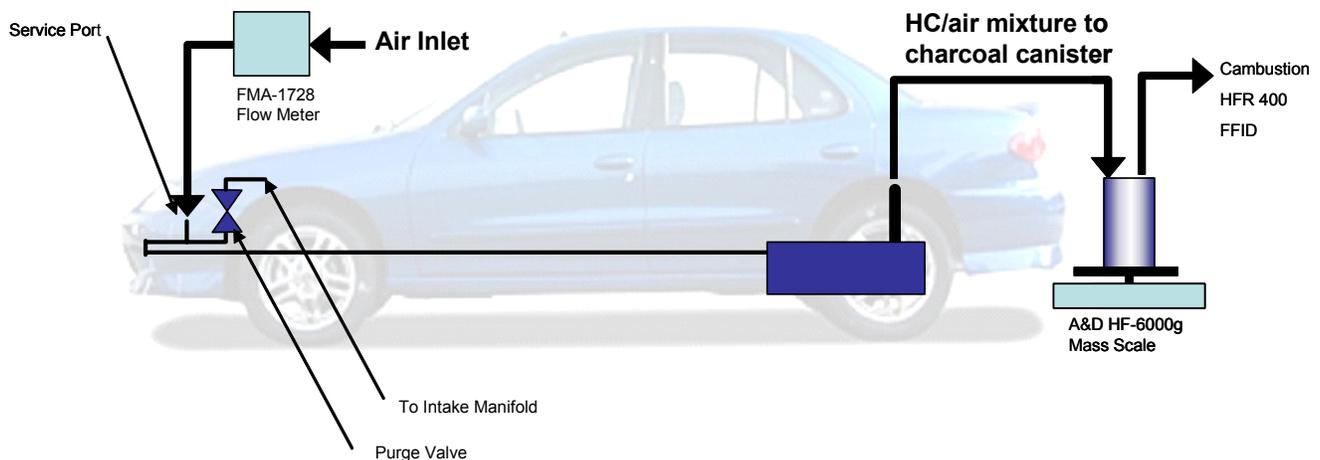
**Figure 1.** Experimental setup for scenario 1. Lab air was fed through a sealed filler cap modified to include an external port fitting. The canister line was connected to a charcoal canister on a scale outside the vehicle, with a FID measuring any hydrocarbons exiting the canister through the vent fitting. The scale weight, air flow rate, and FID output were logged at 6 second intervals.

### 3.1 TEST SCENARIO 1

The first test scenario, as shown in Figure 1, corresponds to the normal test mode for older, pre-OBD-II vehicles with no evap emissions service port. (This would be the bulk of vehicles currently experiencing evap system leaks). The test involved forcing air into the gas filler cap, through the evap system to the charcoal canister and out through the canister vent. Tests in Scenario 1 established the rate of gasoline vapor production in the fuel tank, time/vapor quantity to canister breakthrough and the fraction of vapor absorbed by the canister after it reached breakthrough.

### 3.2 TEST SCENARIO 2

The second test scenario is shown in Figure 2. It involved connecting to the vehicle evap system service port and forcing air through the system to a leak in the area of the fuel tank. Common causes of evap systems failing leak tests are a missing / leaking gas cap or a leak in the tank vapor space. This scenario simulates that case and was used to determine the typical concentrations leaving the tank vapour space during leak testing. Scenario 2 could also represent a planned purge of the evap system with the gas cap removed.



**Figure 2.** Experimental setup to determine hydrocarbon concentration leaving an evaporative emissions system under leak testing conditions. Air entered the system at the evap service port and the hydrocarbon/air mixture exited at the filler neck, where the hydrocarbons were absorbed into the charcoal canister and the mass gain was recorded.

Several test runs were made for the two test scenarios. Two charcoal canisters were used so that, when breakthrough occurred, the canister could be immediately replaced with another canister to provide continuous testing and approximately continuous monitoring of the hydrocarbon emission rate. The saturated charcoal canister was regenerated by a reverse air flow while the next canister was absorbing hydrocarbons. In this way, the same supply of gasoline could be exposed to a long period of continuous air flow to measure both short term and long term vapor behavior during leak testing activities.

To cover a range of gasoline volatilities, further tests were performed with blended gasolines in the out-of-vehicle tank and evap system. Gasoline volatility was measured using a vacuum-based RVP test. (A 0.2 l container is completely filled with liquid fuel and then exposed to an additional 0.8 l vessel which has been evacuated. The entire vessel is immersed in water at 38°C and the absolute pressure is taken as the RVP). Three base gasolines were used directly or as blends for testing at different RVP:

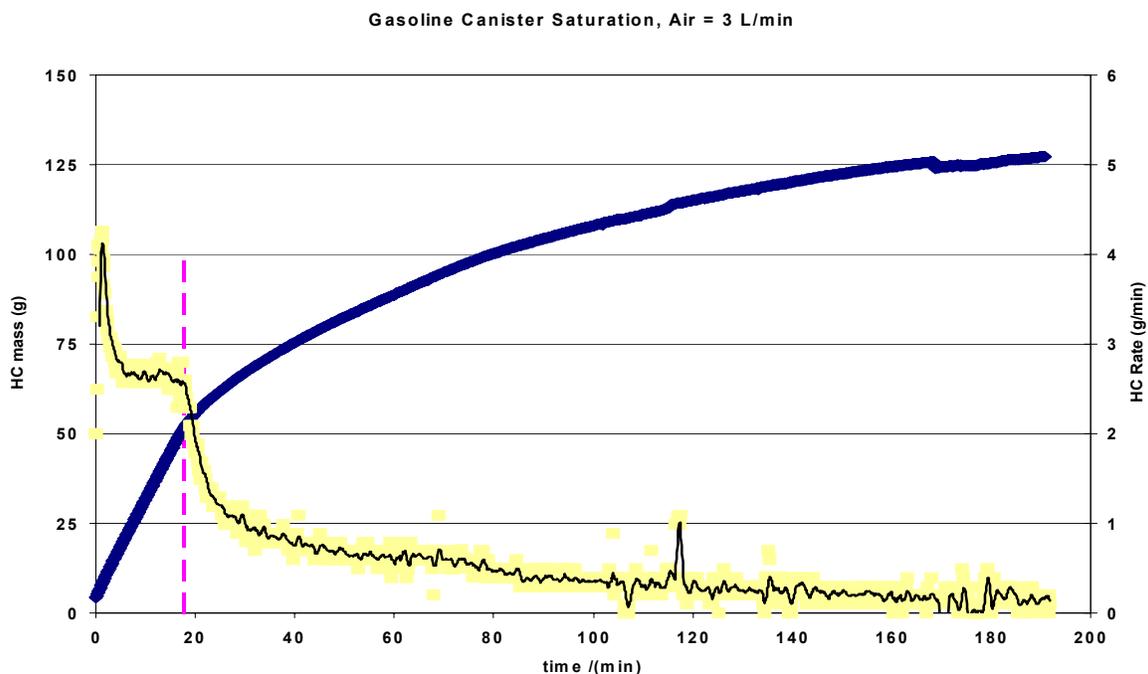
- a regular unleaded with tested RVP of 10.5 psi, (72 kPa)
- a regular unleaded with tested RVP of 8.7 psi, (60 kPa)
- a leaded aviation fuel with tested RVP of 4.3 psi, (30 kPa).

Using these fuels, blends were established which behave the same as California-spec gasolines with RVP in the 7 to 9 psi range.

### 3.0 RESULTS

#### 3.1 Typical Canister Traces During Testing

In every test, the FID hydrocarbon detector at the canister vent showed that the canisters passed essentially zero hydrocarbons until the point of breakthrough. This feature makes canister weight gain a good way to measure the hydrocarbon emission rate from a closed system, at least until the canister saturates. Figure 3 shows a typical canister weight gain trace, (the rising heavy line), and rate of weight gain, (the yellow dots and thin black line) when an air flow imposed through the vehicle fuel tank is vented through the canister. The rate of hydrocarbon trapping shows an early peak as the contents of the saturated fuel tank vapor space are flushed out, then drops to a lower, stable value related to the evaporation rate of fuel vapor. The dashed vertical line indicates the point of breakthrough when hydrocarbons appear at the canister vent, (at 17.6 minutes for this test). After breakthrough, the rate of hydrocarbon adsorption in the canister drops off sharply and then declines further as the canister approaches true saturation.



**Figure 3.** Test of canister trap rate for a thorough saturation at low driving flow rate. Tank  $\frac{1}{2}$  full tank of RVP 10.5 gasoline, 22°C, 3 l/min air driving rate. Heavy line shows rising mass of trapped hydrocarbon vapor. Barred line indicates HC breakthrough at 17.6 minutes (49 grams trapped). Light points and line indicate rate of hydrocarbon trapping (grams/minute).

### **3.2 Gasoline Vapor Concentration in Tank Vapor Space**

Using the relationship proposed in SAE paper 2004-01-0141, (Itakura, Kato and Naoya), a gasoline fuel with 10.5 psi RVP can be expected to have a vapor pressure around 39 kPa at 22°C. Hence, it would commonly be assumed that the saturation vapor concentration would be  $39 \text{ kPa} / 92 \text{ kPa} = 42\%$  vapor. The gasoline vapor displaced in the first few minutes of testing for a tank previously "at rest" should give an indication of the concentration originally in the vapor space. For the test shown in Figure 3, the peak canister weight gain rate was 4.1 g/min. Presuming a vapor molar mass similar to pentane, (72 kg/kmol), the standard density of the vapor would be 2.99 g/ℓ and the standard volumetric vapor flow rate would be 1.37 ℓ/min of gasoline vapor absorbed. If the driving air flow rate was 3 ℓ/min and the fuel evaporation rate was 1 ℓ/min (established later), then the rate of contents displaced out of the tank vapor space would be 4 ℓ/min and the vapor concentration would be  $1.37 / 4 = 34\%$  vapor or about 82% of saturation.

In another similar test on a "rested" fuel tank, the driving air flow was set at 10.7 ℓ/min and the initial peak of hydrocarbon vapor absorption was 7.2 g/min corresponding to 2.41 ℓ/min of vapor. In a total displaced flow of 11.7 ℓ/min, (including the 1 ℓ/min fuel evaporation rate), this indicates only 21% vapor concentration or about 50% of saturated concentration. The decrease in apparent initial vapor concentration occurs because this test method always produces a blend of driving gas and tank contents. Hence, raising the driving gas flow rate lowers the initial concentration of material swept out of the tank vapor space. These results indicate that the initial concentration in the vapor space of a fuel tank is likely to approach the saturated concentration after a sufficient period of "rest" time.

However, even if the vapor space concentration tends to reach the saturation vapor pressure, it is also possible for the vapor concentration to be significantly different from saturation where the tank equilibrium has recently been disturbed. For example, if the tank had been purged recently or the car had been run long enough to alter gasoline temperature, the initial vapor concentrations could be significantly lower or significantly higher than the saturation value implied from the current ambient temperature.

### **3.3 Gasoline Vapor Evaporation Rate in Tank With Air Flowing Through**

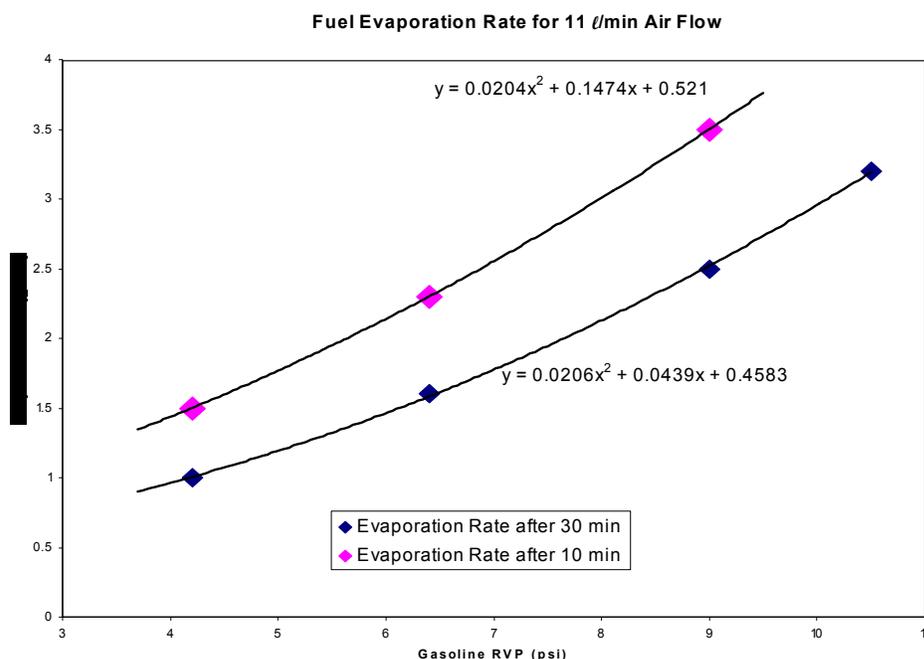
Once the initial surge of hydrocarbon vapors was purged out of the tank, the rate of canister weight gain tended to stabilize at a lower value associated with actual evaporation rate. Over long testing periods, that value declined gradually as the lighter compounds "weathered" out of the fuel surface layer. Table 1 shows experimental results for the 10.5 RVP gasoline, tested with varying air flow rates. Evaporation rate stabilized at a value around 3 g/min, corresponding to about 1 ℓ/min gasoline evaporation. The fact that the evaporation rate remained essentially constant for higher air flow rates (15 and 20 ℓ/min) indicated that the evaporation rate of gasoline was the limiting factor. Lower flow rates (3 ℓ/min) appeared to reduce the evaporation rate marginally.

**Table 1**  
 Gasoline Evaporation Rates at Steady State  
 With Air Forced Through a ½ Full Fuel Tank  
 at Varying Rates and 22°C

Driving Air Flow Rate ℓ/min	Vapor Rate		Continued Testing Time min
	g/min	ℓ/min	
3.1	2.70	0.90	12
10.7	3.61	1.21	10
10.7	3.19	1.07	20
10.7	3.12	1.04	35
10.7	3.17	1.06	39
15.2	2.90	0.97	43
20.1	3.23	1.08	51
20.1	3.10	1.04	55
10.7	2.80	0.93	120

When the testing air flow was continued for two hours, the evaporation rate declined slightly to 0.93 ℓ/min. These tests showed that, once the initial surge of saturated vapor was purged out of the tank, the gasoline evaporation rate remained fairly steady over a period of time longer than any expected leak detection tests.

A series of gasoline evaporation rate tests was run using gasolines of varying RVP in the out-of-vehicle tank and a consistent air flow rate of 11  $\ell$ /min. For these tests, the tank was rinsed and 4  $\ell$  of room-temperature fuel was used each time. The tank was not allowed to come to equilibrium. Testing was started immediately and, after the initial surge of pre-vaporized fuel vapor was purged out of the tank, the fuel evaporation rate was measured after 10 minutes and 30 minutes of testing. Given the small fuel sample of 4  $\ell$ , the 10 minute evaporation rate would be typical of the evaporation rate during leak detection activities and the 30 minute rate would be a measure of the lower evaporation rate expected after considerable weathering of the gasoline. As shown in Figure 4, there is a significant correlation between gasoline volatility (RVP) and evaporation rate. The upper line, "evaporation rate after 10 min" would give the typical evaporation rate for the early stages of a leak detection exercise with the gasoline at room temperature. The lower line, "evaporation rate after 30 min" would give the evaporation rate if the leak detection was continued long enough to weather the gasoline significantly. For typical 7 to 9 psi RVP values, the evaporation rate at 22°C was 2.6 to 3.5 g/min, corresponding to 0.9 to 1.2  $\ell$ /min of fuel vapor flow. After weathering, the gasoline evaporation rate was 70% of the original value. (Note that these evaporation rates are measured with 4  $\ell$  of fuel covering the bottom of the tank at 22°C ambient conditions. A deeper fuel fill would take considerably longer to weather. The actual volatility and thus evaporation rate and weathering rate would go up and down with fuel temperature.)



**Figure 4.** Fuel evaporation rates in a gasoline tank with 11  $\ell$ /min of air flow. 4 liters of fresh fuel at the start of each test, 22°C nominal.

### **3.4 Vapor Concentrations in the Tank with Air Forced Through the Tank**

The vapor concentrations in the fuel tank vapor space are normally above the upper flammable limit, (which is about 7.5 to 8% for gasoline vapor). Forcing air into the tank to test for leaks, (as in Test Scenario 1) or forcing air into the service port and having it travel to a leak at the tank (as in Test Scenario 2) has the potential to dilute the tank vapor space into the flammable range. These two scenarios are the same to the extent that air is being forced through the fuel tank vapor space and carrying vapor out of the tank. They are different to the extent that, in the Scenario 1 case, the air/vapor mixture is being forced out through the evap system charcoal canister where some of the vapor is absorbed. In the Scenario 2 case, the mixture is being forced out through a leak or open filler neck so that mixture goes directly to the atmosphere.

Considering a gasoline with an evaporation rate that produces  $x$   $\ell$ /min of vapor, the typical mixture concentration after the initial purge of the tank vapor space can be approximated as:

$$\% \text{ Vapor} = (x \ell/\text{min}) / (Q \ell/\text{min} + x \ell/\text{min})$$

where  $Q$   $\ell$ /min is the driving air flow provided by the leak detection equipment. This equation would become applicable after a period of time which depends on the driving air flow rate and the volume of vapor space to be purged. Typically, you can assume you are approaching steady state after you have put two purge volumes through a vessel. Hence, the time

$$T_{\text{min}} = 2 * (V \ell) / (Q \ell/\text{min})$$

gives an estimate of the time  $T$  in minutes when the tank is purged and approaching steady state for a tank vapor space volume of  $V$   $\ell$  and driving air flow rate of  $Q$   $\ell$ /min. For example with a 30  $\ell$  tank vapor space and 10  $\ell$ /min driving air flow rate, the vapor space would have had two purge volumes and should be approaching steady state in 6 minutes.

Table 2 shows typical values for the resulting steady state vapor concentrations. Three gasoline evaporation rates are shown: 2  $\ell$ /min, 1  $\ell$ /min and 0.5  $\ell$ /min. This range of values is wider than the 1.2  $\ell$ /min to 0.6  $\ell$ /min range found in testing at ambient temperature with a range of gasoline volatilities. The higher or lower evaporation rates would correspond respectively to testing with warmer / higher vapor pressure fuel or colder / lower vapor pressure fuel. Table 2 also includes a range of assumed flow rates for the driving air flow provided by the leak detection equipment. Values of 3, 8, 11, 15 and 20  $\ell$ /min are used to represent a range from relatively low flow rates such

as might be found with a leak (3 and 8  $\ell/\text{min}$ ), to a normal flow rate specification, (11  $\ell/\text{min}$ ), and higher flow rates claimed by some machines, (15 and 20  $\ell/\text{min}$ ). The final column of Table 2 shows the resulting steady state vapor concentration produced by this combination.

**Table 2**  
 Steady State Gasoline Concentration  
 with Varying Rates of Driving Air Flow  
 and Gasoline Evaporation Rate

Evaporation Rate $\ell/\text{min}$	Driving Air Flow Rate $\ell/\text{min}$	Vapor Concentration %
2	3	40
2	8	20
2	11	15
2	15	12
2	20	9
1	3	25
1	8	11
1	11	8
1	15	6
1	20	5
0.5	3	14
0.5	8	6
0.5	11	4
0.5	15	3
0.5	20	2

For a highly volatile gasoline, evaporating at 2  $\ell/\text{min}$ , the average vapor concentration in the tank vapor space remains above the upper flammable limit for all the specified flow rates. However, it becomes marginal, (9% vapor concentration), with the highest driving air flow rate (20  $\ell/\text{min}$ ). In this situation, weathering would bring the gasoline vapor concentration down into the flammable range as the evaporation rate drops off. For a gasoline which evaporates at 1  $\ell/\text{min}$ , (in the range typical of the 7 to 9 RVP fuels tested), the average steady state vapor concentration is above the flammable limit at low driving air flow rates (3 and 8  $\ell/\text{min}$ ), marginal at the nominal flow rate, (11  $\ell/\text{min}$ ), and falls into the flammable range for higher flow rates (15 and 20  $\ell/\text{min}$ ). Again,

testing long enough to weather the gasoline would drop the evaporation rate and the mixture would become flammable at progressively lower air flow rates. For a slower-evaporating gasoline, (0.5  $\ell$ /min evaporation rate), the range of flow rates producing average flammable vapor concentrations widens to include the normal flow rate values of 11  $\ell$ /min and 8  $\ell$ /min.

Basically, the region of concern is when a high driving air flow rate is combined with a fuel system containing low volatility gasoline and/or cold gasoline and/or weathered gasoline. The high air flow rate might arise due to lack of any built-in limits on a leak detection machine and/or a very "open" evap system being tested. Such an "open" system could include an evap system with an open line or a tank with an open cap. The potential consequence of a flammable mixture inside the evap system and a large opening is that a flash fire ignited either inside or outside the vehicle system might flash to the vapor space in the fuel tank and, burn the flammable mixture, leading to a high internal pressure and a tank rupture which considerably escalates the fire.

### **3.5 Hydrocarbon Flow Through Canisters During Leak Testing**

The test shown in Figure 3 was a typical result for an excessively sustained leak detection test where a low air flow (3  $\ell$ /min) was imposed through the fuel tank / evap system and out the canister, (ie. Test Scenario 1). After the early peak due to flushing the contents of the saturated fuel tank vapor space, the hydrocarbon mass flow rate dropped to a stable rate of 2.7 g/min or a volume flow rate of 0.9  $\ell$ /min. (All flow rates are measured as mass flow and, when expressed as volumetric flows, are at standard conditions). The rate of absorption by the canister is initially equal to the vapor space output rate but then drops off sharply after canister breakthrough. The canister continues to adsorb some hydrocarbon but the majority passes through it. Shortly after breakthrough, the canister absorption rate was about 40% of the vapor coming from the fuel system. With continued operation over a 3 hour period, this dropped to less than 10%, ie. more than 90% of the vapor was passing through the canister.

For the flow rates used in the Figure 3 test, the gasoline vapor concentration arriving at the canister was about 25% vapor. With a 40% to 10% absorption rate, the mixture leaving the canister was in the 15% to 23% concentration range. That range of mixtures is above the upper flammable limit concentration, (around 7.5 to 8% by volume), and is sufficiently concentrated to act as a heavy vapor mixture and sink to the floor. As it mixes with the air in the shop, the canister exhaust would always have a flammable layer and would form a growing volume of flammable mixture with time. This represents a significant flash fire and explosion hazard since heavy vapors form fairly stable layers on the floor and are not easily mixed or moved except by very direct fan action.

Taking 1  $\ell$ /min of gasoline vapor as a typical evaporation rate during leak testing activities, that vapour quantity will mix with about 40 times its volume air to form an ideal flammable mixture and needs to be diluted with more than 80 times its volume of air to put it below the lower flammable limit. Hence, the testing activities which blow air through a fuel tank can produce an ultimate load of 40 to 80  $\ell$ /min of flammable mixture. If the canister is in a normal, purged state at the start of leak detection activities, it may be able to absorb the first 50 grams (17  $\ell$ ), or more, of the vapor displaced from the system without any breakthrough. (If the canister is close to saturation, as might be the case on a vehicle with evap system problems, it will have negligible absorption capacity). Accounting for the higher initial concentrations in the tank vapor space, the

first 50 grams of gasoline vapor would typically be displaced within about 15 or 20 minutes of testing. After that, on-going testing would be generating significant quantities of flammable mixture.

#### **4.0 SUMMARY AND CONCLUSIONS**

Looking back on the questions which triggered this experimental research project, the following answers have been found:

-The initial gasoline vapor concentration in the fuel tank vapor space was not measured precisely in these tests. However, the indications are that the concentration is probably close to the ideal saturated concentration and certainly well above the flammable limit for typical conditions.

-Testing a range of gasoline volatilities (4 to 9 RVP) at normal ambient temperatures provided typical gasoline evaporation rates close to 1 ℓ/minute in a typical 60 ℓ fuel tank. This evaporation rate was consistent over a range of air flows through the fuel tank and not affected by whether the flow entered the tank through an adapted filler cap (Scenario 1) or the OBD-II service port (Scenario 2). The evaporation rates did vary with RVP (0.6 ℓ/min for 4 psi RVP to 1.2 ℓ/min for 9 RVP) and dropped off gradually as the gasoline weathered.

-The consistency of the fuel evaporation rate allowed calculating the steady state fuel vapor concentration during leak testing activities. If an air flow passes through the fuel tank it will tend to produce a flammable mixture inside the system for cases where the fuel volatility / evaporation rate is low and/or the air flow rate is high. The effect is the same whether the air flow enters the tank through the filler neck or through the evap system. The flow exiting the fuel system is particularly likely to be flammable in cases where the flow is high because there is a large opening, (fuel cap off or an open hose) and, in these cases, there is the possibility that a flash fire ignited outside the vehicle can flash back into the fuel system with subsequent increase in damage potential.

-The quantities of hydrocarbon vapor produced during leak detection activities are sufficient to fill a typical evap system charcoal canister to the hydrocarbon breakthrough point in 15 to

20 minutes or less. From that point on, the canister will tend to be emitting a significant quantity of heavy hydrocarbon vapour/air mixture which poses a potential pooling hazard. This situation is likely to occur when the driving flow is provided at the fuel tank and thus purges the fuel tank vapor space through the canister, (ie Scenario 1 for older vehicles without an OBD-II service port). For the alternative test setup, (Scenario 2 for newer vehicles with an OBD-II service port), the canister is unlikely to see much hydrocarbon. However, there is a risk of the tank vapor space contents being forced out a fuel tank vapor space leak. It is important to note that leaks at the fuel tank emit concentrated vapor right from the start of the test since there is no canister absorption.