# Interpretation Techniques of CRC Project E65 Permeation Emissions Can Overestimate Real World Impact

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**Submitted on Behalf of The Renewable Fuels Association**
**by Robert Reynolds**

**Downstream Alternatives Inc.**
**1657 Commerce Dr.**
**Suite 20 B**
**South Bend, IN 46628**
**(574) 250-2811**
**rreynolds-dai@eathlink.net**

## Interpretation Techniques of CRC Project E65 Permeation Emissions Can Overestimate Real World Impact.

Data from CRC Project No. E65 "Fuel Permeation From Automotive Fuel Systems" (September 2004) has greatly advanced the understanding of changes in Permeation Emissions resulting from changes in fuel composition. However, caution must be used in interpretating this data as well as how it is used in estimating or modeling real world emissions impacts.

Two very important areas that must be addressed are the over representation of plastic (non-metallic) fuel tanks in the 10 vehicle test and the affect the preconditioning cycle likely has in causing higher permeation emissions than would be experienced in real world conditions.

Over-Representation of Plastic Fuel Tanks

Vehicles with plastic tanks are over-represented compared to the in-use fleet. This was done intentionally because of the need to have a better understanding of the permeation effect on these tanks. This is very important since plastic tanks provide the greatest surface area through which gasoline components permeate. As an example, Rig #6 (1993 MY) represented all 1992 and 1993 vehicles. Rig #5 (1995 MY) represented 1994 and 1995 model years. Rig #4 (1997 MY) represented 1996 and 1997 model years, and Rig #2 (2000MY) represented one of two rigs for the 1998, 1999, and 2000 model years. Obviously not all vehicles in these nine model years had plastic tanks. In addition, all of the plastic tanks were large tanks ranging in size from 16.5 to 23.0 gallon capacities while the metal tanks ranged from only 13.2 to 17.0 gallon capacities. In effect, the four plastic tanks represented 79.5 gallons capacity of a total of 172.8 gallons capacity total (46%). In short, the surface area for plastic tanks is greater in the test fleet than the in-use fleet.

These 4 test rigs and their emissions profiles on each fuel are listed below.

| | | | Average Emissions –g/day | | |
|---|---|---|---|---|---|
| Rig | Vehicle | Tank | Fuel A | Fuel B | Fuel C |
| 2 | 2000 Honda Odyssey | 20.0 gal -Plastic | 0.64 | 1.43 | 0.58 |
| 4 | 1997 Chrysler Town & Country | 20.0 gal -Plastic | 0.63 | 2.25 | 1.13 |
| 5 | 1995 Ford Ranger | 16.5 gal -Plastic | 9.20 | 11.65 | 11.75 |
| 6 | 1993 Chevrolet Caprice Classic | 23.0 gal -Plastic | 4.55 | 4.89 | 3.55 |

As a comparison, it can be seen that while rigs 1 and 3 (metal tanks) had permeation emissions of only 0.24 grams/day and 0.29 g/d on fuel A, rigs 2 and 4 (plastic tanks) had permeation emissions of 0.64 g/d and 0.63 g/d on the same fuel. This is more than double the permeation emissions of the newer metal fuel rigs.

When one analyzes these 4 newer rigs (i.e. 1-4, used to represent 5 model years) the average permeation emission is 0.45 g/d while the average for the two plastic tanks is 0.635 g/d.

Similar results were seen when these rigs were tested on the other fuels utilized in the project.

Since plastic tanks do not represent 50% of these 5 model years. This clearly results in an overstatement of emissions if the average results are utilized to model those vehicle years.

Thus a factor to correct this impact is needed. An example formula follows:

(MY x PT % x PE) + (MY x MT % x PE) = CAPE

When MY = Model year total vehicles
PT % = Percent of vehicles with plastic tanks
PE = Permeation emissions
MT % = Percent of vehicles with metal tanks
CAPE = Corrected average permeation emissions per model year

A similar formula should be used to correct the overstatement of emissions on fuels B and C.

In short, if the percent of plastic tanks used in this test is corrected to real world plastic tank utilization, the permeation emissions average would fall on all three fuels utilized.

**Effect of Preconditioning Cycles**

The test results cannot be used to accurately estimate in-use fleet permeation emissions without being adjusted. The preconditioning cycle (fuel tank fill levels) for tests performed results in overstating the permeation effect on plastic (non-metal) fuel tanks. The fuel systems were preconditioned with the tanks full at 105˚F in order to stabilize them (i.e. create a reversal in the four week moving emissions average). This procedure is necessary to achieve stabilized results and is based on sound engineering considerations. However, it is different than real world conditions. Steady state tests done in the program show much lower permeation when the tanks are conditioned at only 20% full. Likewise, the 20% preconditioning fill for the diurnal test also resulted in lower emissions on some rigs. Following is a comparison.

**Table # 1**
**Fill Effect – Steady State Test Results**
**Results Comparing 100% fill to 20% fill for Preconditioning**

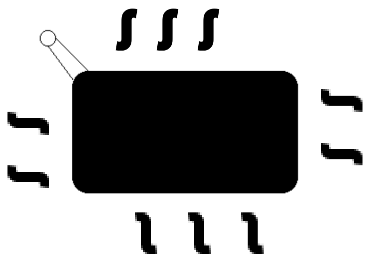
| Rig | Vehicle | 105˚ | 85˚ |
|---|---|---|---|
| **2** | **2000 Honda Odyssey** | **-25%** | **-32%** |
| **4** | **1997 Chrysler Minivan** | **-22%** | **-49%** |
| **5** | **1995 Ford Ranger XL Truck** | **-9%** | **0** |
| **6** | **1993 Chevrolet Caprice Classic** | **-7%** | **+1%** |

**Table # 2**
**Fill Level Effect – Diurnal Test Results**
**Results Comparing 100% fill to 20% fill for Preconditioning**

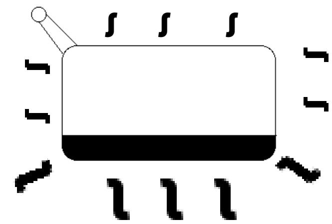
| Rig | Vehicle | Day 1 | Day 2 |
|---|---|---|---|
| **2** | **2000 Honda Odyssey** | **-27%** | **-26%** |
| **4** | **1997 Chrysler Minivan** | **-35%** | **-35%** |
| **5** | **1995 Ford Ranger XL Truck** | **+8%** | **+8%** |
| **6** | **1993 Chevrolet Caprice Classic** | **+10%** | **+20%** |

This is reasonably easy to understand. When a tank is filled to rated capacity, nearly the entire surface of the tank interior is in contact with liquid fuel (see diagram). Whereas at a 20% fill very little of the entire tank surface is in contact with the liquid fuel.

100% Fill 20% Fill



Nearly entire interior surface of tank is saturated with liquid due to constant contact with liquid fuel



Only a small portion of interior surface of tank is saturated with liquid fuel

It is reasonably well understood that liquid will lead to a greater permeation level than the same surface area in contact with vapor only. In the preconditioning cycle, the tanks were filled and held at 105° F. During this period nearly all of the tanks interior surface would become saturated with fuel. As can be seen in Table # 1 all 4 vehicles showed increased emissions at 105° on the steady state emissions test. Two of the four vehicles also showed increases on the 85° steady state test and the same two vehicles showed increases on the California diurnal test cycle.

It is important to point out that the stabilization technique was to keep the tank full (at listed capacity) and the rigs at 105° F until they were determined stable. This is a sound and valid approach to achieve stabilization. However, once designated stable, the vehicle then had the 85° F steady state test, followed by reducing the tank fill to 40% capacity. Rigs then under went the two-day diurnal. This means that when the rigs underwent the diurnal test, the tank walls on the plastic tanks (4 rigs) were likely saturated and may have contributed to the SHED measurement. The result is that some of the permeation was from molecules in the saturated tank walls. This would, of course, not occur in the real world because a) tanks would not set full for such extended periods and b) while exposed to 105° F for some parts of the day, they would certainly not encounter such conditions 24 hours per day for several weeks. Unfortunately at the time the decision was made to assess the preconditioning effect there was no fuel A or B left so only fuel C (non-oxygenated) was tested in this portion of the test. However, since the ethanol blend was shown to have higher permeation emissions the effect would almost certainly be more pronounced on fuel B.

While, as noted, vehicles are rarely full for extended periods, they are also likely not at the 20% fill level for more than a day or two at time. Normally the fuel tank would be cycling between high levels (i.e. 75% or more full) to low levels (i.e. 25% full or less).

This must some how be taken into account. One approach would be to use a more representative 50% fill level assumption in which case one would assume, for example, that in Rig 2 the 25% reduction would be 37.5% of that amount or a 9.375% reduction expressed as (percent change x 37.5) and then applied to the emissions calculation discussed earlier in this paper. It can be reasonably assumed that the ethanol blend factor would be higher but absent test data the same 37.5% reduction would have to be used. The important point is that the preconditioning cycle does have an impact. The one necessitated for the stabilization cycle in the this program, if applied without adjustment, will over state real world emissions.

One issue that is not addressed in the above discussion is tank sloshing, where tank walls are wet above the fill level due to starting, stopping, uneven terrain, etc. However, this would be a small impact because at higher tank temperatures, the liquid on the walls would tend to vaporize and flash off back into the tank headspace.

These are very important issues that must be addressed to prevent over estimating total permeation emissions as well as differences between fuels. Therefore, it is reasonable to use these rigs to develop such an adjustment given that only 10 vehicles are used to try and characterize the entire in-use fleet. While a larger data set would be preferable to develop some type of adjustment, the four rigs are a large part of this test program.