February 27, 2012

MEMORANDUM

To: Brian Menard
From: Chris Lindhjem, ENVIRON International
Subject: Review of "The DELTA Model: Improved Evaporative Emissions Modeling for EPA MOVES, DRAFT / DELIBERATIVE," October 13, 2011

INTRODUCTION

The report, "The DELTA Model: Improved Evaporative Emissions Modeling for EPA MOVES" presents an approach to estimating multi-diurnal vapor venting while a vehicle is parked over several days. This report documents the assumptions, data sources, calculations and limitations used to estimate on-road vehicle evaporative emissions due to multi-day diurnal cycles using the DELTA (Diurnal Emissions Leaving To Atmosphere) model. This new model is associated with updates to the EPA MOVES model in conjunction with the proposed Tier 3 rulemaking.

The approach described uses a model of a single ideal vehicle as a starting point. In addition, there is a description of how DELTA can model emissions of an entire fleet. This includes building a fleet average of the tank vapor generated and tank vapor vented (TVG – TVV) relationship, finding and using a fleet average canister size and tank volume, and producing a fleet average TVG – TVV curve for use in the MOVES model. The report then describes how the single vehicle model is used to describe weighted fleet average behavior.

OVERALL REVIEW

There are several changes that should be made to the DELTA model to better reflect the data, scientific theory, and fleet average behavior. The model appears to oversimplify the single vehicle modeling and does not incorporate all the potential conditions in the estimation of the weighted fleet average vapor venting emissions.

By not incorporating the relationship between vapor generation and canister capture efficiency, the DELTA model does not demonstrate its ability to model the data. The calculation of the effect of backpurge appears to ignore the behavior exhibited by the individual vehicle data provided.

By not incorporating the distributions of all in-use conditions, the weighted fleet average would not reflect the overall relationship between vapor generation and vapor venting emissions. Worst case conditions could provide emission rates at low temperature heat builds, while optimal situations would reduce vapor venting under higher temperature situations. Incorporating all potential in-use situations could markedly change the relationship between ambient conditions and fleet average vapor venting emission predictions currently modeled by DELTA.

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Single Vehicle Modeling

The method described for a single vehicle has two main issues that would affect the single vehicle model presented. These issues involve the apparent assumption that canister capture efficiency is a step function between full capture prior to breakthrough and no capture efficiency after breakthrough. This assumption influences how backpurge affects the canister condition and vapor venting. The breakthrough condition should also be defined as when the initial vapor venting occurs, not necessarily when the vapor venting reaches 2% of loaded weight in order to estimate lower emission events.

The first assumption that the canister will not collect vapor once the breakthrough condition is reached does not follow the basic understanding of how activated carbon captures vapor. For a number of reasons (e.g., pore size distributions, surface area coverage, and range of compounds in the vapor), the capture efficiency for a given partial pressure of vapor should slowly decline as shown in Figure 1 of this review. The effect of incorporating the post-breakthrough efficiency would be to lower the vapor venting until the canister is fully loaded.

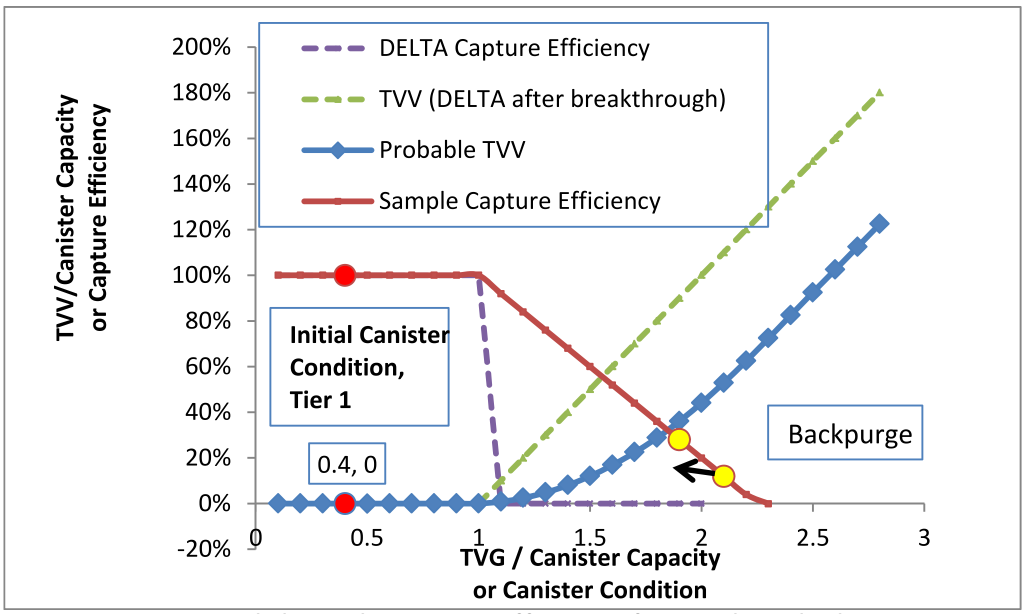

Figure 1. Post-Breakthrough Capture Efficiency for Single Vehicles.

The second assumption that backpurge will bring the canister to a pre-breakthrough condition appears to contradict the individual vehicle results presented in support of the method. Figures 14-17 of the paper demonstrate that vapor venting occurs from the beginning of the next day's vapor generation once the canister has been loaded past breakthrough. That vapor venting emissions would occur early in the next day's heat build indicates that the effect of backpurge is to lower the canister loading based on the day's peak temperature loaded condition, and not from the breakthrough point. The method shown in the report's Figure 6 then does not describe the post-breakthrough backpurge effect; if it had, then the vapor venting would be zero for the beginning vapor generation of each day. Rather, the effect of backpurge might better be modeled to reduce the canister loading in proportion to the ambient vapor drawn through the canister as the tank cools, as shown schematically in Figure 1 above. When the post-backpurged and post-breakthrough canister begins the next day's heat build, the efficiency would be less than 100% and exhibit some immediate vapor venting such as is shown in Figures 14-17.

The report's Figures 14-17 also demonstrate that the single vehicle vapor venting as a function of vapor venting follows an increasing rate as the vapor generation increases. The vapor venting rate would presumably continue to increase until the canister capture efficiency reduces to zero, and from then on the vapor venting rate should equal the vapor generation. This relationship is better described by the suggested post-breakthrough capture efficiency relationship in Figure 1 above and schematically described in the equations below.

Canister condition = Vapor generation x average capture efficiency

Vapor venting = vapor generation x (1 – average capture efficiency)

Where capture efficiency = 100% before breakthrough and f(canister condition) after

Canister condition (beginning of each heat build) = Peak Daily Load - Backpurge

The important finding of the report, demonstrated in Tables 4 and 5, that canister capacity is less than optimal, should be followed up to determine if the canister capacity has actually diminished from deterioration, or that the initial canister loading was responsible for the less than full canister capacity. One method to determine this might be to draw sufficient ambient air through in-use canisters until the weight does not change, record the weight reduced from the additional purge air, and use a loading method such as the one described in the report using butane to determine the in-use full capacity.

The determination of the deterioration and initial loading of canisters has a potential implication for the modeling such that either the canister capacity must be adjusted or the initial loading should be set to a value above zero. The weighted fleet average should account for the range of in-use initial canister loads. Figure 1 above shows how the initial canister load might be incorporated in calculation of the vapor venting emissions by setting an initial canister condition above a zero load.

The canister capacity as measured by the loading of butane may underestimate the canister capacity because, especially for lower RVP fuels, heavier (lower vapor pressure) compounds than butane would be found in the vapor generated. The model even assumes that the vapor has a higher average molecular weight (MW) of 66 than butane (which has a MW of approximately 58), for example. The canister capacity should also be determined for the peak diurnal temperatures to reflect the maximum load each day to account for any heat effects on the canister capacity.

There has been evidence that the tank temperature probably lags the ambient temperatures in most cases (when air circulation is low such as when the vehicle is in an enclosed space), so the modeled tank vapor generation should account for less than peak vapor generation.

Weighted Fleet Average

The refinements suggested here when incorporated may lead to higher or lower emissions than the current approach, depending upon the conditions for which distributions are included for characteristics and in-use conditions. By using distributions of vehicle characteristics, emissions are likely to be nonzero for even low temperature difference heat builds because worst case conditions would be included in the averages. However, determining a fleet average using wide distributions would better reflect the overall fleet behavior by incorporating all situations.

The report notes that determining a weighted fleet average emission rate needs to incorporate tank volume and individual vehicle canister properties (the report might refer to only canister capacity but should also account for the distribution of initial canister loads as well).

But there are several other factors that should be incorporated into the weighted average. One is that the distribution of fill volume fractions should be incorporated into the vapor generation and backpurged calculations. (The 40% fill volume used in the E77 program is not necessarily the in-use fleet average anyway, but rather it follows the official testing protocol.) Whether in DELTA or in MOVES, the frequency of multiple diurnals needs to be incorporated to calculate fleet averaged emissions. The use of all potential distributions of vehicle characteristics (canister capacity and initial day canister load) and fill volume fractions would reduce the chance that there would be a threshold vapor generation below which vapor venting emissions would be zero as described in Figures 21, 23, 24 and 25.

In addition, the researchers should determine if the canister capacity (full capacity compared to no load, regardless of the initial day loading) correlates with tank volume, and add tank volume to Tables 1-3 to describe the comparison. The proper canister capacity to tank volume may be important because the vapor generation (a function of tank and fill volume fraction as well as temperature and RVP) and canister capacity may be balanced and a function of the evaporative emission standards. The use of an average canister capacity, tank volume, and fill volume fraction ignores too many variables that affect emissions for in-use fleets.

EDITORIAL SUGGESTIONS

There may be typos or grammar, but what are described here are suggested additions to fully clarify what has been presented.

One characteristic that has not been discussed is the fuel weathering that occurs. While the DELTA model can be used regardless of weathering, it should be noted that MOVES would need to incorporate fuel weathering in the estimation of in-use RVP (lower than fresh dispensed fuel RVP) or the range in-use in-tanks RVP. In addition, any other inputs (tank temperature, frequency of multi-diurnals, or other input factors) that MOVES may determine as inputs to the multi-diurnal emission calculation should be discussed.

Figure 13

Statement: Canister weight is plotted against vapor generation.

Comment: Should the 'canister weight' be relabeled as vapor vented? This figure is difficult to follow because the vapor generation decreases at the end of each day's heat build, so should the vapor generation decreasing be plotted at all? This figure is also used to demonstrate how the data is transformed from canister weight to vapor venting in Figures 14-17, but it does not follow directly that canister weight can be converted to vapor venting.

Figure 14

Statement: Vapor generation reduces between one day and the next.

Comment: The vapor generation increases except (it appears) between one day and the next where it decreases. Should the vapor generation continue to increase, or is there an assumption that backpurge reduces the vapor generation during the cooling phase of the test? It appears that this occurs in the Appendix B code in the expression below where the TVG is subtracted by a datapoint[2]. Without the raw data, it is not possible to fully review the results to discern where vapor generation is shown to reduce from one day to the next.

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else:

   if test_Dict[key][i+1][1] >= highPointTVV and datapoint[8] - output_Dict[key][-1][7] > 120:
          highPointTVG = highPointTVG - datapoint[2]
```

Figures 15-17

Statement: Comparisons between the fleet average prediction and the individual vehicle results.

Comment: The figures need to show calculated fleet averages for the individual vehicle results presented, so that the data and DELTA prediction can be compared on an equivalent weighted fleet average basis. I suspect that the data driven fleet average may show a different shape of the curve representing the relationship between vapor vented and vapor generation than the DELTA predicted fleet average, regardless of the effect of canister capacity (or the effect of initial canister loads).

Figures 18 and 19

Statement: The figures are labeled as test vehicles from the E77 program.

Comment: Given the smooth regular curves, the figures are more probably DELTA estimates based on the canister conditions from the E77 program. The labels should clearly describe these as theoretical emission rates for various vehicle conditions and not actual data.