Continuing Ethanol Permeation Issues

August 25, 2006

Overview

- **Revised AIR estimate of ethanol permeation**
- **"Closeness" of the ARB and AIR estimates**
- **Comments on ARB's August 16 Ethanol Permeation Presentation**

Increased On-Road Permeation Due to Ethanol, Based on E-65 E6 Data (g/day)

Vehicle Group	AIR Current Estimate	Revision Using Phase III Data
Pre-1991	2.03	2.03
1991-1995	0.86	0.86
Enhanced Evap	0.80	0.80
Near Zero (LEV II evap)	0.43 (est.)	**0.10**
PZEV	0.12 (est.)	**0.015**

Increases based on 65-105℉ temperature

The results on the right hand side of this table come from the August, 2006 report CRC Project No. E-65-3. Page 21 of the report contains two Figures (18 and 19) for Rigs 11 (near zero evap) and 12 (PZEV). The results are shown below:

Rig 11 (near zero evap)

48 mg/day on E0

144 mg/day on E6

Difference is 96 mg/day, which rounds to 0.10 g/day

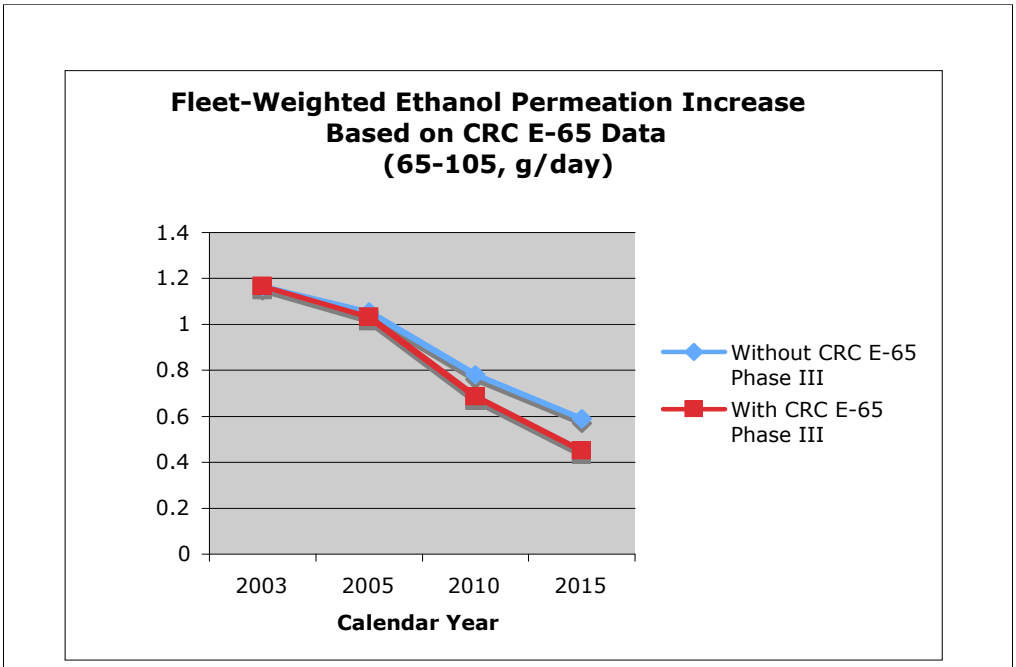
Riig 12 (PZEV)

35 mg/day on E0

50 mg/day on E6

Difference is 15 mg/day, or 0.015 g/day

The remainder of the numbers were developed by AIR from the original E-65 data, an are described in our permeation report for API.



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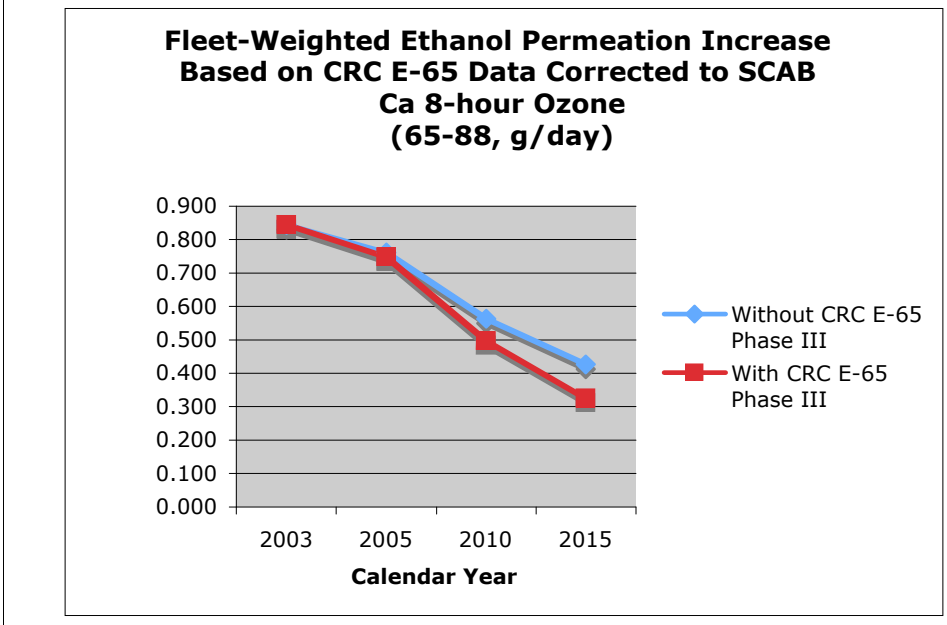
This plot is developed from the numbers on the previous page (both columns) and fleet information on the VMT fractions by model year group (model year groups shown in previous page) from the EMFAC2002 model. Each number is a fleet-wieghted average number in the calendar year. For example, in 2010, the increase appears to be about 0.8 g/day without the Phase III data. This is for the fleet of car, LDTs, and HDGVs (I.e., all gasoline vehicles) as whole.

The numbers above are based on the 65-105 temperature excursion, and are uncorrected for temperature in this plot. The next page shows these values corrected for SCAB Ca 8-hour ozone temperatures.

The plot shows a steady reduction in the fleet-average increase in permeation emissions due to ethanol. This reduction accelerates with the inclusion of the Phase III data.

If we were to extend this plot beyond 2015, it would keep getting lower, because the near zero increase is only 0.1, and PZEVs are 0.015. So it would drive pretty close to zero in 2030 and beyond.



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These are the numbers from the previous page, corrected for temperature. The method used to correct for temperature is described in detail in our report for API entitled “Effects of Gasoline Ethanol Blends on Permeation Emissions Contribution to VOC Inventory from On-Road and Off-Road Sources”, March 3, 2005 (Section 4.4, ppg 35-37). Basically, we developed temperature correction factors for the ethanol g/day increases from the 85F and 105F steady state temperature results, and the assumption (confirmed from other permeation test results) that permeation increases about 2x for every 10C.

In this plot, we correct to the Ca 8-hour ozone temperatures that ARB developed for the SCAB, which are from 65-88F.

Impact of CRC E-65 Phase III Data on ARB's Analysis

Vehicles	ARB "Normal" ETOH Augmentation Ratio	Augmentation Ratio Using E-65 Phase III Data
LEV II Near Zero	2.55	3.0
PZEV	2.55	1.4

LEV II Near Zero is close to ARB "normal"

PZEV is much lower, suggesting need for lower ratio for these vehicles

The 2.55 augmentation ratio for normals comes from the work Ben Hancock developed on the "normals" in the CRC E-65 data, which represent 8 out of the 10 vehicles.

The data provided on page 3 of this presentation allow the estimate of the ratios shown in the right-hand column.

The PZEV ratio is much lower than 2.55, therefore, PZEVs should probably have this ratio instead of 2.55.

The LEV II near zero vehicle could be combined with the other normal vehicles, and ARB could estimate a new "normal " ratio, which will be slightly higher than 2.55.

AIR Revised Analysis

Ethanol On Road Permeation Impacts in the South Coast in 2010				
Source	Temps	Pop.	CRC E-65 Phase III?	Amount (tpd)
ARB	8-hour	New	No	8.7
AIR, orig	1-hour	Old	No	5.3
AIR, new	8-hour	New	No	6.4
AIR, new	8-hour	New	Yes	5.6

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The first row estimate of 8.7 tpd was taken from Ben Hancock's June 30 presentation entitled "On-and Off-Road Ethanol Emission Impacts", (page 14).

The second row is from AIR's report for API, in section 7.1.2, page 62 (Table 26).

The 3rd and fourth rows were developed from the 2nd row and the ratio of per vehicle ethanol increases from AIR's model. The average, per-vehicle increases due to ethanol are shown below:

AIR, orig: 0.466g/day (see Table 24 of AIR report)

AIR, new, 8-hour, with new pop, w/o Phase III: 0.564 g/day

AIR, new, 8-hour, new pop, w/ Phase III: 0.497 g/day

3rd row: 0.564/0.466 * (5.3) = 6.4 tpd

4ht row: 0.497/0.466 * (5.3) = 5.6 tpd

Differences

- Without CRC E-65 Phase III Effects
  - New AIR Estimate: 6.4 tpd
  - ARB Current Estimate: 8.7 tpd
  - **Difference: 2.3 tpd, or 26%**
- Uisng CRC E-65 Phase III Data (AIR Only)
  - New AIR Estimate: 5.6 tpd
  - ARB Current Estimate: 8.7 tpd
  - **Difference: 3.1 tpd, or 36%**

These numbers were estimated from the inventories on the previous page

Are Differences Due to Different Hot Soak and Running Loss Methods?

- Both methods estimate permeation during hot soak and running loss periods
  - ARB method is explicit
  - AIR method estimates the same as during diurnal/resting losses
  - Both methods estimate total emissions from a 24 hour period
- AIR estimate of amount due to hot soak and running losses (2010)
  - About 1.4 tpd in SCAB
- AIR estimate of ARB amount due to hot soak and running loss (2010)
  - About 2.0 tpd
- Difference is 0.6 tpd
- This does not appear to explain all of difference

ARB method attempts to estimate increase permeation emission during hot soak and running operation. Basically, emissions during these periods are treated as resting permeation emissions at a higher temperature. Tank temperatures are based on a test on one vehicle, I think. AIR method assumes first approximation of emissions can be estimated with E-65 results. ARB has stated that this is the primary reason why ARB's estimates are higher than AIR's. But is it the primary reason?

ARB estimates that the typical vehicle is in hot soak or running mode about 5 hours per day. Most of the this is the hot soak mode, which lasts for 45 minutes every time a trip ends and the key is turned off. (ARB 5-hour estimate shown in the backup slides presented August 11, 2006)

AIR estimate of hot soak and running loss effect is then 5hrs/24hrs * 6.4 = 1.33 tpd, so 1.4t pd above should be revised downward to 1.3 tpd.

June 17, 2006 presentation by Hancock shows that the combined hot soak and running loss permeation increase in the SCAB using the new Ca 8-hour ozone temperatures is 1.9 tpd. (I had estimated 2 tpd without the June 16 memo - Ben pointed out that he had presented this estimate on June 16.

Difference is 1.9 tpd - 1.4 tpd - 0.5 tpd, therefore, this issue explains 0.5 of the 2.3 tpd difference (0.5/2.3 = 22%), and not the whole difference.

Close Enough?

- Ethanol permeation in Predictive Model adds 4% to OFP
- If AIR's estimate were used, it would add
  - 3% to OFP, without Phase III effects
  - 2.6% to OFP, with Phase III effects
- Difference is 1-1.4% Ozone Forming Potential (OFP) in Predictive Model
- 1 to 1.4% OFP in **Draft Predictive Model** is worth
  - **0.2 to 0.3 RVP reduction, or**
  - **7-11 F T50 reduction, or**
  - **4-6% aromatics reduction;**
  - **Cannot get 1-1.4% OFP reduction with lower sulfur**
- **Conclusion: differences are very significant**

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See page 31 of ARB's August 15 presentation for 4 % increase. This is based on the 8.7 tpd increase in South Coast and elsewhere in the state. Thus, 8.7 tpd increase in the SCAB caused a 4% increase in OFP. (The PM is based on the state, but the proportions are relative).

AIR's increase is 26% less than ARB's (6.4 tpd vs 8.7 tpd) for the 'without Phase III effects', therefore, if AIR's impacts were used instead of ARB's the increase would be 3% in OFP instead of 4%. AIR's increase is 38% less with the Phase III effects, and 38% less than 4% is 2.5%.

The changes in fuel properties were determined by examination of the impacts of what change in fuel parameters would be necessary to achieve a 1-1.4% reduction in OFP from the ARB charts presented August 16 from the draft PM model.

Comments on ARB's August 16 Presentation (Response to WSPA's Comments)

Issue	ARB Comment
Fuel Temperature Correlation (Tank vs Ambient)	Accepted test method based on ambient temps No existing data Will require major restructuring of EMFAC
Multiplicative Correction	Results are similar to additive
Temperature Dependence	Steady-state and dynamic methods agree over 60°to 90℉

These comments were described in Hancock's August 15 presentation.

Tank vs Ambient Temperatures

- Why is this important?
  - Because permeation emissions from EMFAC, generated during the resting loss period when ambient temperature in SHED is DECLINING, are being used to estimate permeation emissions during DIURNAL, when ambient temperature is RISING
  - These are then used to estimate PERMEATION FRACTION for the diurnal emissions, which is then used with ethanol augmentation ratios to estimate ethanol increase for fleet
- ARB's Use of CRC E-65 Data
  - ARB's only use of the E-65 data is to develop ethanol augmentation ratios for permeation emissions
  - Everything else comes from EMFAC, not E-65
    - PERMEATION FRACTION for each process developed entirely from EMFAC equations

Tank vs Ambient Temperatures (cont)

- Why isn't it okay to use permeation emissions developed during ambient temperature declines in a SHED to estimate permeation emissions during diurnal?
  - Because the fuel tank temperatures are lower than ambient during heating and higher than ambient than during cooling.
  - Using the correct (I.e., tank) temperatures should lead to lower estimated permeation emissions during diurnal periods, and thus, a lower permeation fraction during diurnal
- If this factor is taken into account for estimating the permeation fraction during diurnal, would all of the EMFAC evap data and methods have to be adjusted for this effect?
  - No. ARB's evap estimates do not rely on the PERMEATION FRACTION – only the ethanol increases use this, and it is already utilized in ARB's ethanol modeling

Tank vs Ambient Temperatures (cont)

- So, using tank temperatures fits in with ARB's approach for EMFAC programming, and can be incorporated easily
- Taking this into account for permeation increases due to ethanol is consistent with other EMFAC estimates for evaporative emissions

What is the Effect?

- ARB has estimated that using tank temperatures reduces the diurnal PERMEATION FRACTIONS by 50%
- According to ARB, this would reduce ethanol permeation emissions by 20% (diurnal + resting)
- 20% of 8.7 tpd in the SCAB is 1.7 tpd or about 0.8% of the OFP increase in the Draft Predictive Model

ARB's analysis of this effect is shown in the backup slides for August 15 workshop.

Multiplicative Correction

- ARB comparison of similarity to additive approach - two concerns
  - Combines comparison of additive effects and different methods of estimating temperature effects so one cannot tell which is which
  - Assumes that EMFAC results can be directly compared to straight average from E-65, which they cannot
    - EMFAC results have a “fleet weighting”
    - Average of E65 results has no “fleet weighting”

This slide addresses the numbers presented by ARB in the backup slides for August 11 - the one entitled “ Temperature Dependence Results Comparison, where ARB compares E65 hour by hour results to EMFAC inventories and results estimated with a a temperature model based on the steady state results.

The E65 hour by hour results are not fleet weighted - they are a straight average of the test data.

The EMFAC results are fleet weighted.

The steady state results are not fleet weighted. The steady state results can be compared to the E65 hour by hour result, but it is probably inappropriate to compare both of these to the EMFAC results because the latter is fleet weighted, while the former sources are not.

This slide also does not truly test an additive model. The results based on the steady state temperature model are not really additive ethanol permeation results corrected to a different temperature, instead, they are results that are estimated on an hour by hour basis on a emissions model that is based on the steady-state results.

Permeation Temperature Dependence

- EMFAC permeation temperature dependence for moderate emitters is unsupportable theoretically
  - Normal emitters double permeation emissions every 10-11°C
  - E65 permeation data indicates doubling every 9-11° C
  - Ford paper indicates doubling every 8-12°C
  - Moderate emitters double every 6°C
    - Effects of residual windshield washer fluid in SHED tests?
- ARB should assume same temperature sensitivity for moderates in EMFAC as for normals
  - Size of this effect can only be determined by running EMFAC

This slide refers to a slide in the backup slides for August 15 that is labeled “EMFAC Resting Temperature Dependence”. Note that the % effect per degree C for moderate fuel injected vehicles is much higher than all the other vehicles/emitter groups. These temperature relationships are based on SHED 24-hour test data used in the EMFAC model. While these data should be good, we have noticed much more dependency of emissions on temperature on the cooling side than we have on the heating side in E-65. There is the possibility that hydrocarbons on adosrbing on the SHED condenser during cooling, and are being released during heating. If in-use vehicles are tested with any residual windshield washer fluid, this could be affecting the total emissions and the temperature sensitivity during cooling. This is being further investigated in E-77.