Final Report

Review of ARB's New Ethanol Permeation Estimates for On-Road and Off-Road Vehicles and Equipment

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1.0 Executive Summary

ARB's new estimate of the impact of ethanol on VOC emissions in the South Coast Air Basin is that ethanol increases permeation VOC emissions by about 19 tpd on an average summer ozone day. This is composed of about 11.5 tpd from on-road sources, and 7.4 tpd from off-road equipment and portable containers. On more extreme temperature ozone days, the Staff estimates that ethanol's impact could be 2.5 times this amount.

Our review revealed a number of areas where we think the Staff's estimate is overestimated. The most significant of these are as follows:

1. There is no technical justification that we can think of for applying an ethanol augmentation ratio for leaking vehicles. If this is removed, the ethanol increase on an average summer ozone violation day is reduced by 1 tpd, or about 10%.

2. Staff assumed that on-road resting losses are 90% permeation emissions, over all temperatures and for all evaporative technologies. This fraction should really be established through testing of different technologies. In the meantime we believe that the fraction of permeation emissions for moderate emitting enhanced evaporative vehicles is lower than 90%, perhaps 70% or 80%. The fraction would also be lower for older evaporative technologies. This assumption could affect the ethanol permeation estimate on an average summer ozone violation day by 3-4 tpd.

3. The fraction of permeation emissions during the diurnal period for on-road vehicles is being overestimated, because permeation emissions are more related to fuel system temperatures than to ambient temperatures, and the methodology used by ARB for the diurnal process is not taking into account the well-documented lag between fuel temperature and ambient temperatures. This may affect the on-road ethanol permeation estimate on an average summer ozone violation day by 2-3 tpd.

4. For portable fuel containers, the percent increases on ethanol should be estimated as the percent increases in the average emissions of the different containers, not the average of the various percent increases.

2.0 Introduction

On November 3, 2005, ARB presented updated estimates of the impact of gasoline-ethanol blends on California permeation VOC emissions inventories for on-road vehicles, and off-road equipment and portable fuel containers. [1] The results for a summer average ozone day in the South Coast Air Basin are shown below.

Increase in on-road VOC:	11.5 tpd
Increase in off-road[1] VOC:	7.4 tpd
Total impact:	18.9 tpd

Diurnal and resting loss permeation constitute the majority (9.3 tpd or 81%) of the 11.5 tpd increase in VOC for on-road vehicles. The remaining 19% is estimated to be hot soak and running loss permeation. For the off-road impact, 77% of the impact is due to off-road equipment, and 23% to portable fuel containers.

ARB also presented new estimates of the on-road permeation impact at higher temperatures. The ethanol permeation impacts at the higher temperatures were much larger than the above values. For example, at the higher temperatures measured in the Southern California Oxidant Study (SCOS) - 70F to 98F - the ethanol impact for on-road vehicles is estimated to be 2.56 times larger than the above estimate.

However, the new values for summer average ozone days in the South Coast, especially for on-road vehicles, are substantially lower than previous estimates by the ARB. The purpose of this report is to review these new estimates. This report is divided into the following sections:

- Review of On-Road Impacts
- Review of Off-Road Impacts

2.0 Review of On-Road Impacts

This section compares the permeation impacts in the November 3 2005 ARB analysis with previous ARB estimates. It then describes the four general changes to the modeling method that ARB has adopted in the November 3 analysis. Finally, it summarizes our concerns with the November 3 analysis and our recommendations for changes.

2.1 Comparison of Before and After On-Road Impacts at Summer Average Temperatures

In a February 2005 report, ARB developed an estimate of the permeation impact on the South Coast Air Basin during a typical ozone day in calendar year 2004. [2] ARB estimated that on-road permeation emissions would increase by 17.4 tpd. This is significantly higher than the 11.5 tpd estimated in November, and reflected the Staff's analysis at that time. For off-road equipment and portable fuel containers, the report estimated 10 tpd in the South Coast. The comparison of the current versus past estimates is shown in Table 1.

[1] Includes portable fuel containers

Table 1. Comparison of ARB and AIR Permeation Impacts, in South Coast Air Basin, Typical Summer Ozone Day in 2004*			
Estimate	On-road	Off-road	Total
ARB, February 2005	17.4	10.0	27.4
ARB. November 2005	11.5	7.4	18.9
% Lower	34%	26%	31%
AIR Estimate	7.0	3.3	10.3

* The AIR estimate is for 2003.

Table 1 indicates that the more recent estimates, during a typical ozone day in the South Coast, are about 30% less than the previous estimates. However, they are still higher than the AIR estimates. [3]

2.2 What Has Changed in ARB's New Analysis?

There are four areas where ARB's analysis has been updated:

- Estimate of ethanol effects by emissions "regime"
- More complete technology group mappings
- Updated permeation fractions for all technology groups
- Sensitivity analysis using SCOS temperatures

These are discussed in the sections below.

Estimate of ethanol effects by emissions "regime"

In the February 2005 analysis, ARB combined all of the CRC test vehicles into one group to determine the percent increase in permeation emissions due to ethanol. The November 2005 ARB analysis separates higher emitting vehicles from lower emitting vehicles, and develops separate increases for the two emitter "regimes." The higher emitting regime has a lower ethanol "augmentation ratio" than the lower emitting vehicles. This may have been done in response to AIR's comment that it was the high ratios on the low emitting vehicles that were driving the permeation inventory impacts associated with ethanol.

The diurnal ethanol augmentation ratios for the normal emitters in the CRC data are about 2.6/1, and for the higher emitters are about 1.2/1. These are shown on slides 5 and 6 of the November 3 ARB presentation.[2] Both ratios are constant with varying temperature.

[2] All slides referenced in this memo are shown in Attachment 1.

ARB also developed an ethanol augmentation ratio for liquid leakers. This ratio is 1.05/1. There should not be any augmentation for liquid leakers – ethanol does not cause gasoline to leak faster (like it does cause permeation to accelerate), nor does it cause more fuel to evaporate when it forms a puddle – all of a puddle of gasoline eventually evaporates, whether it contains ethanol or not. Therefore, there is no reasonable rationale for augmenting liquid leakers, and this augmentation should be eliminated. Liquid leakers add 1 tpd (out of a total of 11.5 tpd) to the ethanol effects inventory for an average summer ozone episode, and 3.6 tpd (out of a total of 29.5 tpd) to the ethanol effects for the higher temperature (SCAB 2005 SCOS Temperature Profile) day.

More complete technology group mappings for permeation fractions

In their November 2005 analysis, the ARB classified the CRC E65 data by vehicle technology/model year categories for the purpose of estimating permeation fractions. This classification is shown in Slides 10 and 11 of the November 3rd presentation. For example, on Slide 10, EMFAC Tech groups 1 and 2 utilize permeation fractions that were estimated from the running loss equations for pre-1970 carbureted vehicles, diurnal/resting loss permeation fractions estimated from the diurnal and resting loss equations for pre-1977 carbureted vehicles, and hot soak permeation fractions estimated from the hot soak and resting losses of (also) pre-1977 carbureted vehicles.

Unfortunately, the tables on Slides 10 and 11 do not list what the EMFAC tech groups are, so it is difficult to determine based on evaluation of the table whether the mapping is correct. We have pulled the tech group definitions out of EMFAC model, and these are shown in Attachment 2. We reviewed most of these selections, and have no reason to believe that the selections made by ARB are incorrect.

Updated permeation fractions for all technology groups

ARB developed updated permeation fractions by evaporative process. In the February 2005 ARB analysis, these permeation fractions were developed only for enhanced evaporative vehicles, and the fractions for this category were applied to all vehicles. In the November 2005 analysis, ARB developed separate process-specific permeation fractions for many different evaporative technologies that are present in the fleet. The updated permeation fractions for enhanced evaporative vehicles are shown in slides 9,14 and 16 for diurnal emissions, running losses and hot soak emissions, respectively. The methods used to develop these fractions are the same as the ARB used before. The hot soak and running loss permeation fractions are quite low, usually less than 10%. The permeation fraction for diurnal is significantly higher (Slide 9) than the running loss and hot soak fractions. Resting losses are assumed to be 90% permeation emissions.

We think that the methods used to develop all of the permeation fractions by process are in serious error and, when assembled together for how vehicles actually operate, result in conclusions that just do not make sense. This is the primary reason that AIR estimated the permeation increases from CRC E-65 fleet, temperature corrected these permeation increases and then applied these increases by vehicle class to the California fleet. The AIR procedure, by design, does not require one to estimate the permeation fraction by evaporative process, since this is very difficult to do without a significant amount of new test data. This is discussed further in Section 2.3.

Sensitivity analysis using SCOS temperatures

In the November 2005 analysis, ARB developed on-road ethanol permeation impacts for an ozone day that is hotter than the average ozone day. ARB used temperatures for the SCOS (Southern California Oxidant Study) episode, which are 70F to 98F (average of 84F). The average ozone day in the South Coast is 63F to 84F (average of 74F). A comparison of these diurnal temperatures is shown in Slide 22. The impacts of the higher temperatures on evaporative emissions for on-road vehicles is shown in Table 3.

Table 3. On-Road Ethanol Permeation Impacts at Average Ozone and SCOS Temperatures in the South Coast Air Basin (tpd)

Evaporative Source	Average Ozone Day	SCOS Episode
Diurnal (includes resting losses)	9.3	23.4
Running Loss	1.2	3.1
Hot Soak	1.0	3.0
Total	11.5	29.5

ARB estimates that the higher temperatures increase the ethanol permeation emissions by a factor of 2.56. This is too much of an increase in permeation emissions for these changes in temperature. Other research has shown that permeation emissions can double for a 10 degree C increase. The average increase between these two days is about 10F, or 6C, thus, the increase in ethanol permeation emissions should be about 1.6, not 2.6. The reasons for this increase being too high could trace back to significant errors in the development of the permeation fractions by process and temperature.

2.3 Concerns With the New Analysis

We have already mentioned that the liquid leaker augmentation should be eliminated. A second major concern is the permeation fractions. A third concern is the temperature sensitivity, but this could be related mainly to the permeation fractions by process and temperature. These issues are discussed in the remainder of this section.

Our concern with the diurnal permeation fraction stems from an analysis of the diurnal ethanol increase at SCOS temperatures. According to slide #28, the diurnal increase is 1.64 g/day per vehicle at a temperature of 70F to 98F (average of 84F). But the increase for the CRC fleet of vehicles was only 1.5 g/day, and the maximum diurnal temperature was higher, at 105F (average of 84F). Logically, there is no rationale for the ARB g/day estimate to be higher than the CRC average, when the maximum temperatures are significantly lower. [3,4] Table 4 compares the diurnal permeation emissions from the normal and moderate emitters in the CRC "fleet" and the EMFAC "fleet" and shows that the two fleets are very similar by emitter category.

Table 4. Comparison of Diurnal Permeation Emissions Between CRC Fleet and EMFAC Fleet (on MTBE gasoline)

Fleet	Normal Emitters	Moderate Emitters
EMFAC	1.00 g/day	5.48 g/day
CRC	1.00 g/day	6.5 g/day

The table shows that the diurnal permeation emissions for the normal emitters are identical, and those for the CRC fleet of moderate emitters are higher than for the EMFAC fleet. Thus, differences in average fleet emissions between EMFAC and the CRC test sample does not appear to explain the discrepancy between the permeation increases. Also, the development of the ethanol augmentation ratios for diurnal emissions for normal emitters and moderate emitters was reasonable. This means that the only remaining factor that could be in error is likely the permeation fractions.

AIR considered estimating the increase in permeation emissions using a similar method to the method currently used by the ARB. We rejected this method, however, because it involved estimating the permeation fraction of emissions for each of the four evaporative processes – diurnal, resting, running and hot soak. We thought it would be essential to have data that was specifically collected to determine these permeation fractions by process, in order to estimate these correctly. We knew of no such data, so we selected a different method of estimating the ethanol permeation increases, which is described in our report.

In order to understand our comments on these issues, it is important to comprehend ARB's definitions of the four evaporative processes. The definitions are tied to times of the day, and to whether the vehicle is operated or not, instead of to fundamental evaporative processes. Diurnal emissions are any evaporative emissions that occur in a vehicle that is not operated, while the ambient temperature is rising, and that are not hot soak emissions. Resting emissions are any evaporative emissions that occur when the vehicle is not being operated, and the temperature is either constant or declining, and are not hot soak emissions. Running losses are any evaporative emissions that occur when the vehicle is being operated. Finally, hot soak emissions are any evaporative emissions that occur in the first 40 minutes after the engine is turned off.

[3] There are valid reasons why the ARB estimate could be higher although the temperature is lower – fleet differences, for example. If the CRC fleet is somehow much different than the EMFAC in-use fleet, then there could be valid reasons for a difference. As we show later in this analysis, there are no significant fleet emission difference between the CRC fleet and the EMFAC fleet. This is good, because the CRC vehicles were carefully chosen to represent the California fleet.

[4] The average temperatures of the test procedure and SCOS episode are the same – 84F. But the maximum temperature of the test procedure is much higher – 105F vs 98F, and permeation emissions are not linear with temperature, i.e., they generally double every 10C. So the estimated emissions on the SCOS temperature day should be lower than the average emissions of the test fleet tested at the test temperatures. In other words, the SCOS emissions should be 1.2-1.3 g/day, instead of 1.64 g/day.

The three specific mechanisms by which evaporative emissions can occur are permeation, breathing, and leaks. Any of these three mechanisms can occur during the four evaporative processes described above. This is why, with the ARB method that the permeation fractions for each process have to be established. The ethanol augmentation ratios developed by the Staff apply only to the permeation emissions. If any emissions due to breathing or leaks are included with the permeation emissions, then the ethanol effect will be overestimated.

The ARB staff did not have data that was specifically collected to evaluate permeation fractions either. To estimate the permeation fractions, Staff assumed first that 90% of resting emissions are permeation emissions, regardless of the ambient or fuel tank temperature, or time of day. Resting emissions do vary with temperature, but Staff assumed that the fraction of resting emissions that are permeation emissions does not vary with temperature. Next, Staff estimated 90% of resting emissions, diurnal emissions, hot soak emissions and running loss emissions over specific temperatures. These estimates came from specific equations that estimate these emissions by technology/standard type. Finally, ARB estimated permeation fractions by dividing the resting losses by the other emissions.

We do not have any reason to doubt the basic overall running loss, diurnal, hot soak, or resting loss emissions as estimated by the Staff. These estimates have been made from test data on real vehicles operating under these conditions. However, there are 3 specific assumptions that are made in this process of estimating permeation fractions:

1. The permeation fraction of resting losses is 90%.
2. This fraction does not change with temperature.
3. That resting losses generated from test data during an ambient temperature decline are the same during an ambient temperature increase.

Each of these assumptions is discussed below.

Assumption #1: Permeation fraction of resting losses is 90%

As discussed earlier, resting losses are those that are experienced by a vehicle at rest, when the ambient temperature is constant or declining. When the ambient temperature is declining, usually the tank temperature is declining, and so the fuel tank pulls vapor back from the canister (so-called “back-purge”). Under these conditions, if the vehicle has no leaks, nearly all of the evaporative emissions should be due to permeation through fuel system components. However, there is one major exception to this. When the ambient temperature is increasing or declining, the fuel tank temperature “lags” the ambient temperature. This lag can be as much as 2-3 hours. [4, 5, 6] Thus, it is possible that when the ambient temperature is first declining, the tank fuel temperature can still be increasing, if it is lower than the ambient temperature. The tank temperature will increase until the ambient temperature equals the ambient temperature. In the early stages of resting losses, when the ambient temperature is constant or declining, and the fuel tank temperature is still increasing, it is possible for the vehicle to experience some breathing losses through the canister, and in this case, the permeation fraction of emissions could be quite low.

For "normal" emitting vehicles subject to the enhanced evaporative standards, these breathing losses may be close to zero. But a vehicle that has been parked for 4 days and has a fairly full canister, or an older vehicle without the canister capacity of the enhanced evaporative vehicle, may experience breathing losses in the first 2-3 hours of ARB's resting losses, and would have a much lower permeation fraction in this time period. Whether 90% is the correct number or not, is not known, nor was it established through testing. It is likely to be higher for enhanced evaporative vehicles (and near zero evaporative vehicles) than earlier technologies (i.e., pre-enhanced evap). The fraction of resting losses that are permeation emissions should be established through testing. We think that 90% is probably as good number a number as any for enhanced evaporative normal vehicles in the absence of testing, but moderates and older vehicles should have a lower fraction, perhaps 70-80%, for the time being (until testing is performed). [6,7]

Assumption #2: The fraction does not change with temperature

As indicated in the discussion above, the permeation fraction could be significantly lower than 90% in the first 2 hours of the resting loss period when the temperature is constant or declining, but at the high temperatures of the day. Clearly there is a temperature dependence here, and as mentioned above, this could be more firmly established through testing. In this case, one would not have to assume a constant fraction for resting losses, but the fraction would vary with temperature.

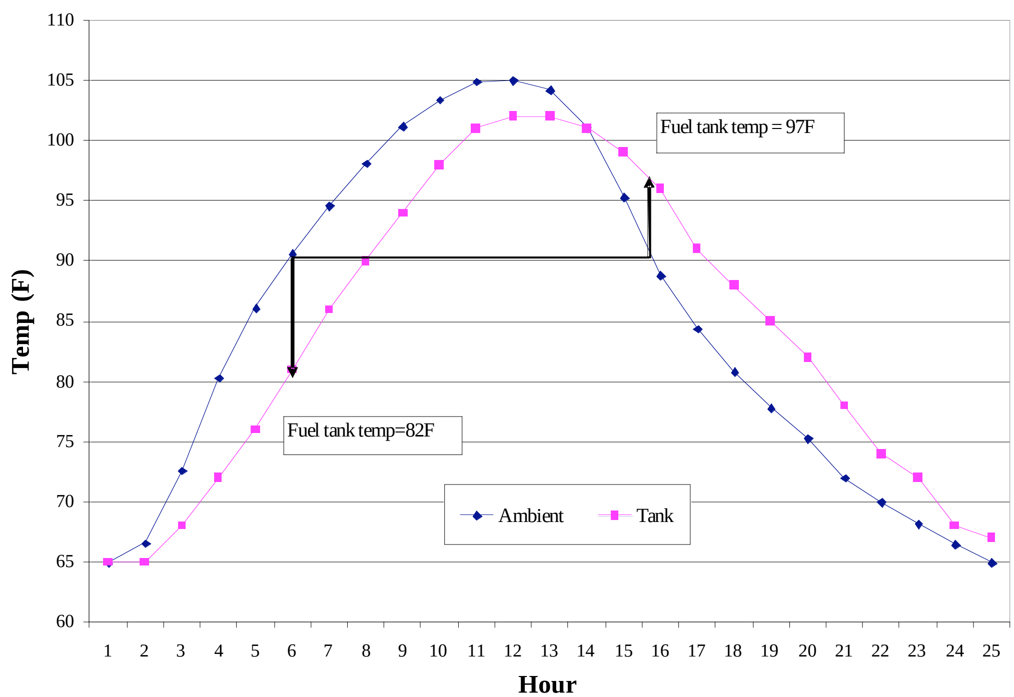
It is certainly possible to establish the permeation fraction of emissions via testing. One method would be to attempt to determine the "signature" of vapor emissions vs permeation emissions on several vehicles tested over a 24-hour temperature cycle. The vapor emissions may be predominantly "light ends" of gasoline like propane and pentane, while the permeation emissions would have a signature more like whole gasoline. Then, a number of vehicles would have to be tested over 24-hour temperature cycles, and the analysis would determine from the mass of emissions during the resting period and the signature of emissions which are vapor emissions vs permeation emissions. The resting permeation fraction could be estimated from these two different results. It would be important to test a fleet of vehicles that are representative of what is on the road in California today, similar to the fleet used in the CRC E-65 testing.

A second and perhaps better method for estimating the permeation fraction of emissions would be to vent all gasoline vapor emissions from the fuel tank to a location outside the SHED, collect these, and analyze the mass of the vapor. The SHED test results would be purely permeation emissions, and emissions collected outside the SHED would be the breathing losses. Dividing the permeation emissions (SHED emissions) by the total emissions would result in the permeation fraction. This method could also be used for determining the permeation fraction for both hot soak and running loss emissions.

Assumption #3: Resting losses generated from test data during an ambient temperature decline are the same during an ambient temperature increase.

The resting emissions equation for vehicles is generated by analyzing test data from a 24-hour SHED test, when the ambient temperature is constant or declining. For example, ARB's equation can predict the emissions at 90F for normal enhanced evaporative vehicles. ARB then multiplies this by 90%, and the assumption is made that whenever the ambient temperature is 90F, a vehicle experiences the same emission rate. However, fuel system permeation is a function of fuel system temperature, not ambient temperature. Fuel system temperature is related to ambient temperature, but as discussed earlier, the fuel tank temperature lags the ambient temperature (the fuel tank because of its surface area is the larges source of permeation emissions). Thus, the permeation emissions estimated at 90F are really for a fuel system temperature that is 5-7 F higher than 90F since the ambient temperature is declining. This would not be the case when the ambient temperature is rising. When the ambient temperature is rising and the ambient temperature is 90F, the fuel system temperature is probably 5-10F less than 90F. This is illustrated for a hypothetical vehicle in Figure 1. This relationship would be somewhat vehicle-dependent, but all vehicles display this to some degree.

Figure 1. Ambient Temperature vs Fuel Tank Temperature



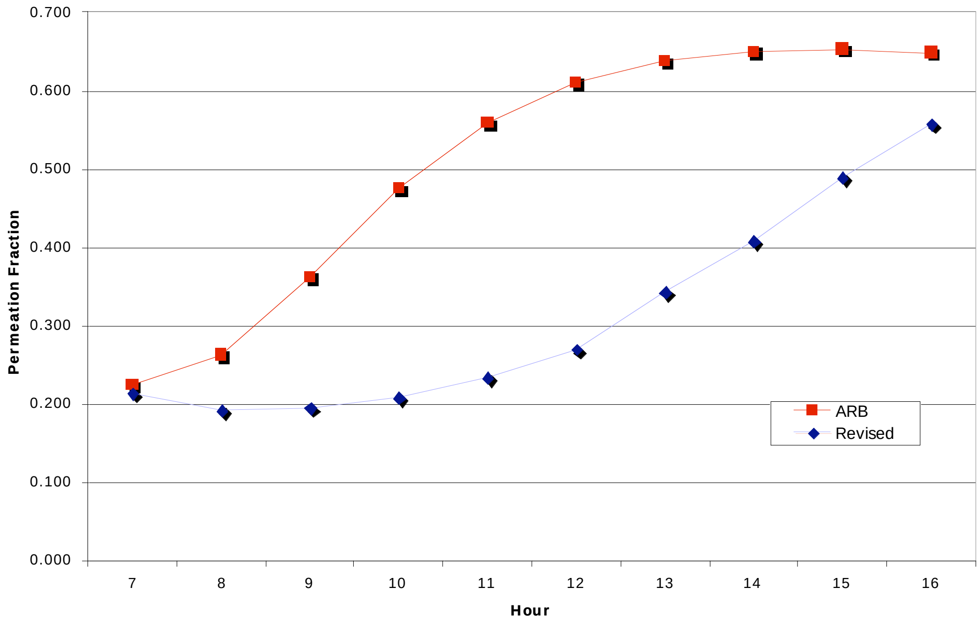
Thus, when permeation emissions are estimated from resting losses to estimate the diurnal permeation fraction, ARB must use a lower temperature profile that is more indicative of the fuel system temperature when the ambient temperature is rising. [5] The diurnal profile must be several degrees less than the ambient profile. This will reduce the permeation emissions estimated during the diurnal period, significantly reducing the diurnal permeation fraction. This should solve the twin problems of the base permeation increase due to ethanol being too high, and also the excessive sensitivity of the ethanol increase to temperature.

Figure 2 shows a comparison between diurnal permeation fractions for the ARB case, and for a revised case where the tank temperature lags the ambient temperature. This comparison is shown for the hours of 7 am to 4 pm when the ambient temperature is rising, and the vehicle is not operated. At all other times of the day, if the vehicle were not operated, under the ARB assumption the fraction would be 0.90. In this comparison, the fuel tank temperature assumed was 4-7F below the ambient temperature, except near 4 pm, where the two temperatures were much closer together. This is not atypical, but we believe this should be based on data on actual vehicles (which is available from various sources which have already been referenced). Revising the permeation emissions based on actual fuel system temperature will have a significant affect on the ethanol permeation inventory.

It is not clear to us whether similar corrections should be made for the permeation emission estimates during running losses and hot soak periods as well. However, these periods are much shorter than the diurnal and resting loss periods, and the ethanol effects for running losses and hot soak emissions are much smaller than for diurnal and resting losses.

[5] It is okay to use the ambient temperature profile to estimate permeation emissions during resting losses, because this profile already has the "correct" lag built into it.

Figure 2. Comparison of Diurnal Permeation Fractions Between 7 AM and 4PM, ARB vs Revised



In summary, we have three comments on the on-road ethanol permeation emissions:

1. Eliminate the ethanol augmentation for liquid leaks.

2. Reduce the resting loss permeation fraction of enhanced evap and later moderate emitters, and older vehicles to 70-80% instead of 90%.

3. Use temperatures lower than ambient to estimate permeation emissions during the diurnal period. These should be based on data where both fuel tank temperatures and ambient temperatures were measured simultaneously.

If ARB were to adopt these recommendations, we expect ARB's ethanol permeation increases for on-road vehicles to come much closer to AIR's, in spite of the fact that ARB's estimates explicitly include running losses and hot soak emissions. ARB's diurnal increases may be below AIR's estimate, so that when ARB adds the diurnal, running loss, and hot soak, it may approximate the AIR estimate, or be slightly higher. [6] Also, adopting these recommendations should also reduce the temperature

[6] In the AIR method, the increase in permeation emissions due to ethanol for running loss and hot soak processes is approximated with the diurnal and resting loss increases. The running and hot soak permeation losses with ethanol are probably slightly higher, and are a function of how hot the permeable parts of the fuel system get under operation as opposed to their temperatures under no vehicle operation. If they are actually hotter (and increased air flow during operation does not mitigate the increase), then the ARB estimate should be a little higher than the AIR estimate.

sensitivity of the increase in permeation emissions due to ethanol to a more reasonable level.

3.0 Review of the Off-Road Impacts

The off-road ethanol permeation inventory impacts previously estimated by ARB (in February 2005) were very sketchy and will not be reviewed here. The first section below reviews the data and methodology underlying the off-road estimates presented by ARB on November 3, 2005. The second section summarizes our concerns with ARB's November 3, 2005 estimates. Portable fuel containers, off-road equipment and off-road vehicles are included in these discussions.

3.1 ARB's Analysis

ARB's analysis is covered very briefly in the November 3rd presentation, but is described in more detail in a January 20, 2006 memo obtained from the Staff. [8] The memo covers both equipment and portable fuel containers.

The increase in off-road permeation emissions due to ethanol in ARB's newest analysis is summarized below in Table 5. The inventories include both equipment and PFCs. The temperatures are summer average, in calendar year 2004.

Table 5. Permeation Emissions from Off-Road Sources (tpd)

Area	MTBE	ETOH	Difference
Statewide	86.6	107.4	20.8
South Coast	30.8	38.2	7.4

<u>Equipment</u>

The increases in emissions for all off-road equipment and off-road vehicles were developed from tests on 5 lawnmowers on fuels containing MTBE and ethanol. The RVP's of the different fuels were held nearly constant at 7 RVP. Lawnmowers were tested utilizing the ARB diurnal test procedure with temperatures of 65F to 105F, and were preconditioned on each fuel prior to testing. Each mower was filled to the 50% level prior to testing. Both diurnal and hot soak tests were performed (running loss tests were not).

For diurnal and resting losses, ARB separated the 24-hour test into the diurnal period and resting period, where the diurnal period is defined by rising cell temperature, and resting period is defined by falling test temperature. ARB then used the hourly emissions to develop relationships between the ratio in ETOH/MTBE emissions and temperature, similar to the process used for on-road vehicles. These relationships are a function of starting temperature and delta temperature, and are shown in Attachment 3. Basically, the ETOH/MTBE ratio increases with increasing starting temperature and also with an increasing delta temperature. We checked these ratios against the overall average increase of the 24-hour data for all 5 lawnmowers, and they appear reasonable. For example, the average increase for all 5 lawnmowers on ethanol was about 40%. The two figures in Attachment 3 indicate that a starting temperature of 75F and a temperature delta of 20F would result in a diurnal ratio of 1.32 for diurnal emissions and 1.34 for resting losses (read the starting temperature on the x axis, the delta on the y axis, and locate the ratio closet to the intersection of these two points).

These diurnal and resting ETOH/MTBE ratios vs temperature are applied to the permeation emissions of all on-road equipment. They were developed only on lawnmowers, and without any permeation controls. ARB has adopted rules to control permeation emissions from off-road equipment. It is not known if the ETOH/MTBE ratios would be different on equipment with fuel tanks and hoses that are subject to stringent permeation controls. It is also not clear if these ratios would be significantly different if they were developed based on a more representative group off-road equipment and off-road vehicles. On this point, our comment is that this is a very narrow range of equipment to develop these ratios on, and the ARB should be testing other equipment to see if these ratios can properly represent the entire gamut of off-road equipment and vehicles.

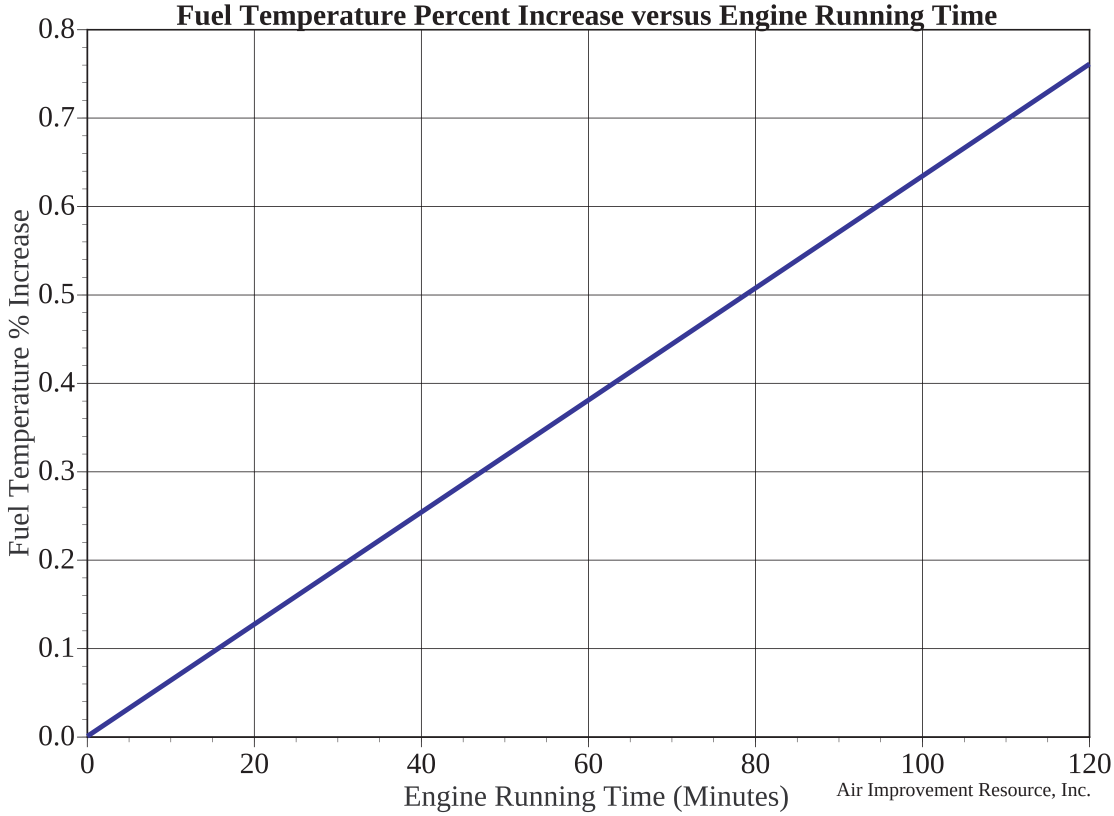
Many types of commercial off-road equipment are equipped with metal fuel tanks. These types of equipment would not be expected to have the same ETOH/MTBE ratios as equipment with plastic tanks. The OFFROAD model divides each category of equipment into those with metal vs plastic tanks.

Staff referenced previous testing of equipment that indicated that 70% of the permeation emissions from a lawnmower come from the fuel hose, and 30% from the fuel tank (while the surface area of hose is much smaller than tank, the permeation rates for hoses are generally many times more than for plastic tanks). For equipment fitted with metal tanks, Staff is estimating 70% of the ethanol permeation increase of the lawnmowers.

For hot soak and running loss emissions, Staff is modeling these as essentially a diurnal ethanol permeation increase, but with temperatures generally hotter than the diurnal. The Staff is using an equation of the increase in fuel temperature with operating time. For example, if a non-road equipment engine is started when the ambient temperature is 75F, and is operated for one hour, and the fuel temperature increases by 8F, then this is being modeled the same as a diurnal (omitting the resting loss part) with starting temperature of 75F and delta temperature of 8F. This is probably okay, but the fuel tank temperature relationship vs time comes from on-road vehicles, not from tests of fuel tank temperature on off-road equipment. This relationship is shown in Figure 2 below.

Figure 2

Fuel Temperature Percent Increase versus Engine Running Time



The figure shows very little temperature increase with time – at 60 minutes, the percent increase in fuel tank temperature is only 0.4%, so if the starting temperature is 75F, then the delta is only 0.3F. This seems almost insignificant. In reality, it is probably quite variable, just like it is for cars. For example, a lawnmower with a fuel tank strapped onto the engine would probably experience a greater temperature increase. A lawn and garden tractor, however, with a larger tank further away from the engine would probably experience very little increase. For nearly all off-road equipment with carbureted engines, there is no fuel recirculation from the engine, like there used to be on many light duty vehicles.[7]

3.2 Portable Fuel Containers

For portable containers, ARB tested a number of plastic containers with and without permeation barrier treatments. The two barrier treatments were fluorination and sulfonation. Container sizes ranged from 1.25 to 6.6 gallons. The tanks were preconditioned on each fuel, sealed with a polyethylene coupon, then SHED tested on the ARB 24-hour procedure (65-105F). On average, ARB estimated that untreated containers experienced a 56% increase in emissions, and sulfonated containers experience a 38% increase in emissions with ethanol. While ARB also developed an increase for fluorinated

[7] Most light duty vehicles with fuel injection do not have fuel recirculation anymore. This reduces fuel tank heating during vehicle operation, making it easier to meet running loss tests.

containers, it was very high (104%), and ARB assumes that permeation-controlled PFCs are all sulfonated, and none are fluorinated.

AIR checked the data for these percent increases, and discovered that they were estimated by determining the averages of the percent increases, instead of determining the average emissions, and then determining the percent increase of the average. For example, the percent increase in emissions for untreated containers varied between -13% and 140%. It is not proper to determine average percent increases this way. When AIR determined the average emissions first, and then determined percent increase in the average emissions, we found that untreated tanks experienced increases of 54%, and sulfonated tanks increased by 28%. Thus, we believe ARB should revise these two estimates, and in doing so, the ethanol permeation impacts on PFCs will be lower, especially in the future when all PFCs are sulfonated.

3.3 Concerns with Off-road Estimates

The following points summarize our concerns with the off-road ethanol permeation increases:

- The database for adjusting the ethanol permeation inventories for off-road equipment – 5 lawnmowers – is inadequate and should be expanded to include one or two other equipment types, for example, and lawn and garden tractor and a generator.

- The method of using on-road tank temperature increase data to model running loss increases is also inadequate. Data on tank temperature increases during operation is needed for off-road equipment. EPA has generated some of these data.

- For portable fuel containers, the percent increases on ethanol should be estimated as the percent increase in the average emissions for different containers, not the averages of the percent increases.

References

1. “EMFAC Model Ethanol Permeation Modeling”, PTSD Mobile Source Analysis Branch, Analysis Section, November 3, 2005.

2. “A Summary of the Staff’s Assessment Regarding The Effect of Ethanol in California Gasoline on Emissions”, ARB, March 2005.

3. “Effects of Gasoline Ethanol Blends on Permeation Emissions Contribution to VOC Inventory From On-Road and Off-Road Sources”, Final Report, AIR for API, February 12, 2005.

4. SAE891121, “Evaporative Emissions Under Real-Time Conditions”, Haskew, and Cadman, May 2-4, 1990.

5. SAE901110, “The Development of a Real-Time Evaporative Emission Test”, Haskew, Cadman, and Liberty, May 1-4, 1990.

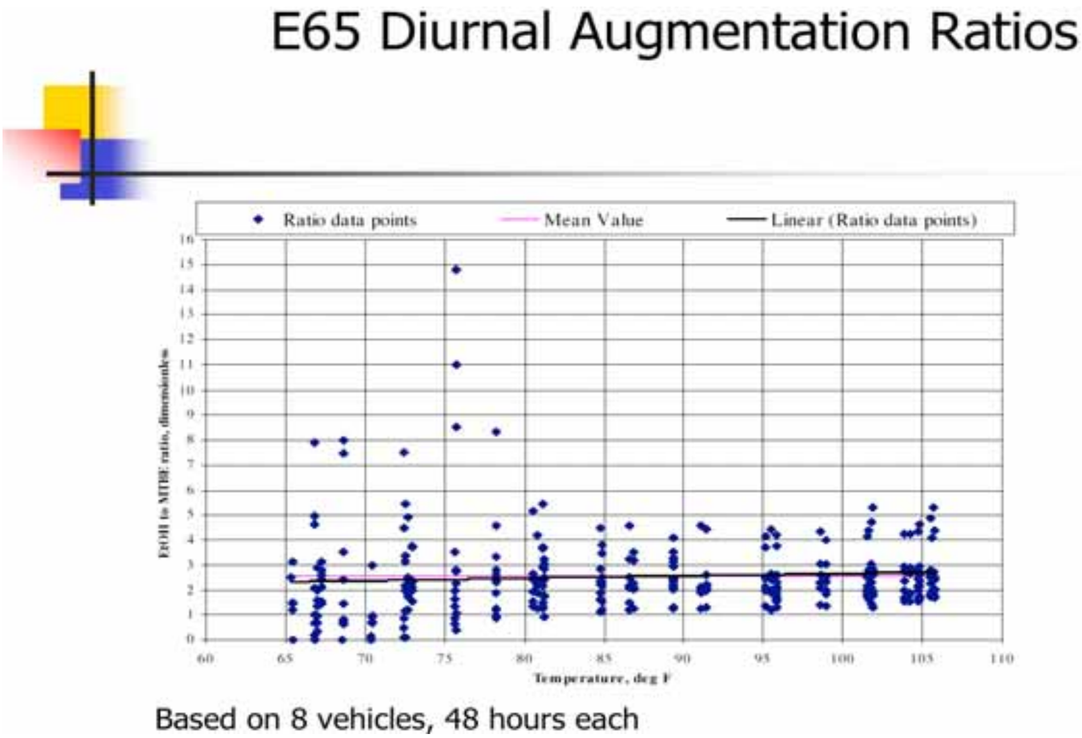
6. SAE1999-01-1463, “Diurnal Emissions From In-Use Vehicles”, Haskew and Liberty, May 3-6, 1999.

7. SAE1999-01-1464, “Running Loss Emissions from In-Use Vehicles”, Haskew, Eng, Liberty, and Reuter, May 3-6, 1999.

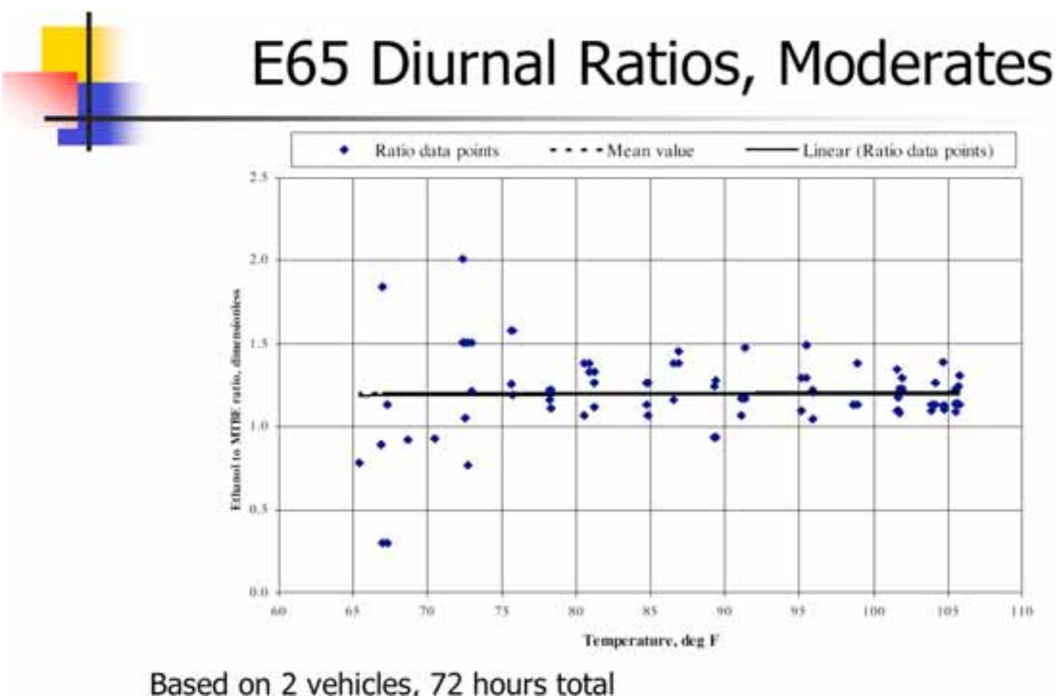
8. Estimation of the Impact of Ethanol on Off-road Evaporative Emissions, Walter Wong, ARB (1/20/06).

Attachment 1
Selected Slides from November 3, 2005 ARB Presentation

Slide # 5

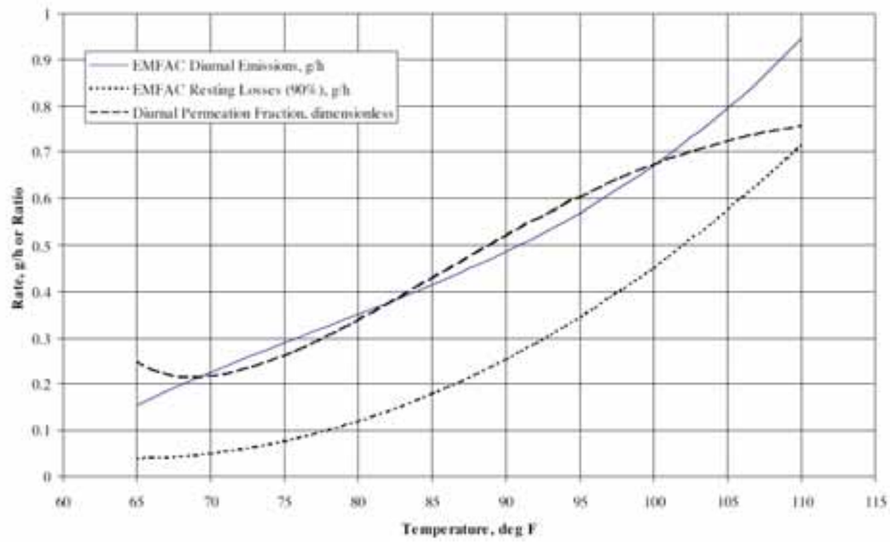


Slide # 6



Slide # 9

Diurnal Permeation Fraction



Slide # 10

Tech Group Correlation Mapping

EMFAC2002 Tech Group Mapping	Vehicle Type	Running Loss Grouping		Diurnal / Resting Grouping		Hot Soak Grouping	
1, 21	Car/Truck	Carb	Pre-1970	Carb	Pre-77	Carb	Pre-77
2, 3	Car	Carb	1970-76				
4, 5	Car	Carb	1977+	Carb	77+	Carb	77+
6, 7, 8, 9, 10, 12, 13	Car	TBI/PFI	All Pre-Enhanced Evap	FI	79-94	FI	86+
14,	Car	TBI/PFI	Enhanced Evap(1)	FI	Enhanced	FI	Enhanced
15, 17	Car	TBI/PFI	Cloned From Enh Evap above	FI	Zero Evap	FI	Zero Evap

Slide # 11

Tech Group Correlation Mapping

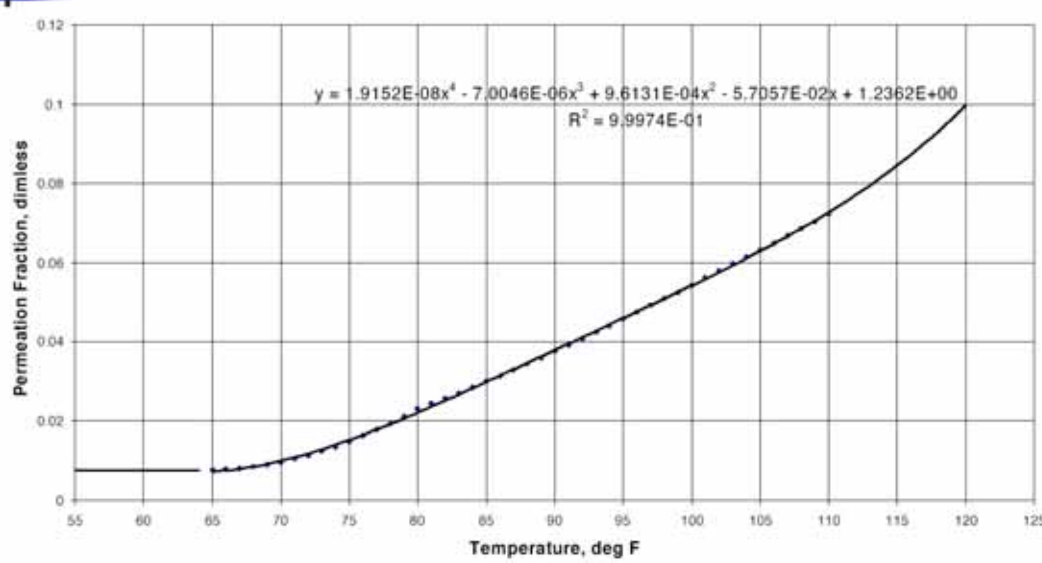
EMFAC2002 Tech Group Mapping	Vehicle Type	Running Loss Grouping		Diurnal / Resting Grouping		Hot Soak Grouping	
22, 23	Truck	Carb	Pre-1980	Carb	Pre-77	Carb	Pre-77
24, 25	Truck	Carb	1980+	Carb	77+	Carb	77+
26, 27, 28, 29, 30, 31, 32, 33	Truck	TBI/PFI	All	FI	79-94	FI	86+
34	Truck	TBI/PFI	Enhanced Evap(1)	FI	Enhanced	FI	Enhanced
35, 37	Truck	TBI/PFI	Cloned From Enh Evap above	FI	Zero Evap	FI	Zero Evap

Note: TBI is throttle-body injection. PFI is port fuel injection. Carb is carbureted.

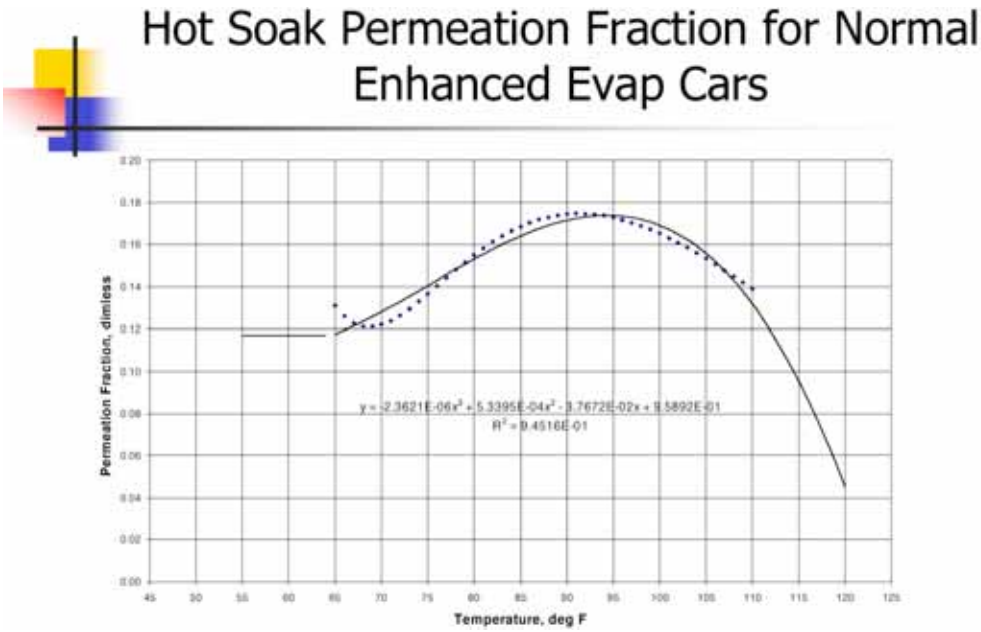
1) Note for Diurnal / Resting and Hot Soak emissions, the truck rates have been cloned from cars.
2) For Hot Soak emissions, the Pre-Enhanced Evap FI group has 3 tech groups (pre79, 79-85, and 86+). I suggest using rates from the 86+ grouping since its rates are based on a larger data set.
3) For running losses, the zero evap group cloned from the enh evap group.
4) Note, not doing anything for near-zero evap.

Slide # 14

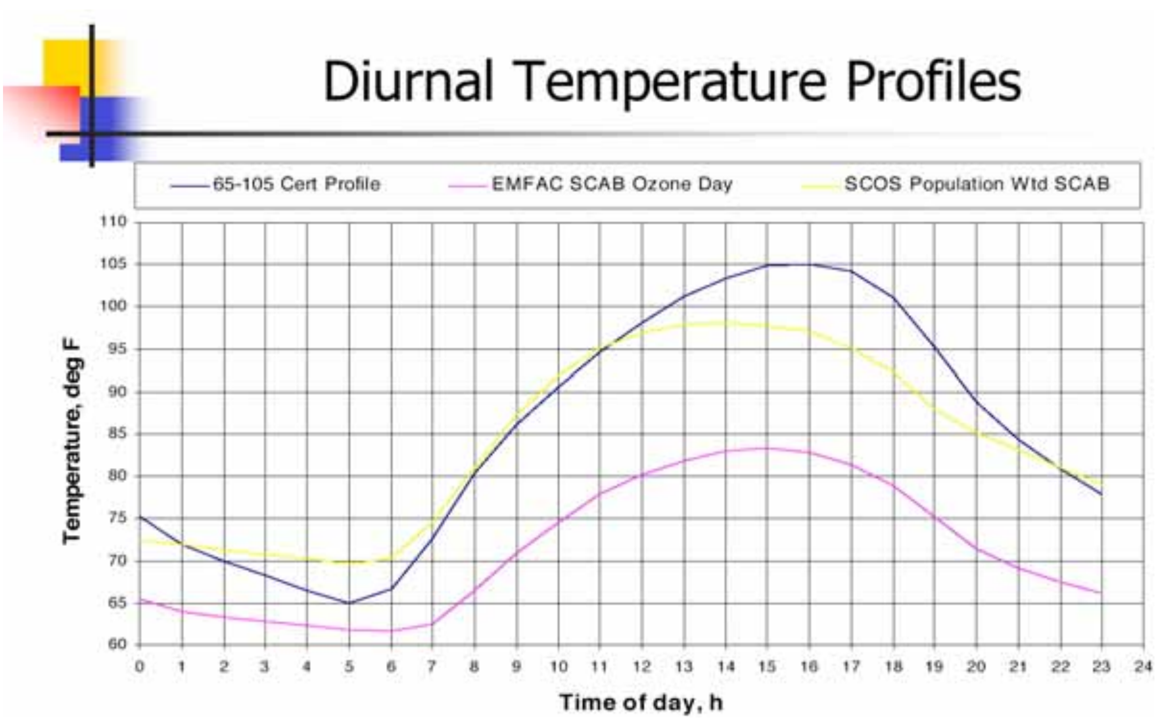
Running Loss Permeation Fraction for Normal Enhanced Evap Cars



Slide # 16



Slide # 22



Slide # 28

Onroad Ethanol Permeation Inventory Effects (SCAB 2005 SCOS Temp Profile)

		Ph 2 Gaso w/MTBE				Ph 2 Gaso w/EtOH				Increase
		Normals	Moderates	Liq Lkrs	Total	Normals	Moderates	Liq Lkrs	Total	
No of Vehicles		9,515,994	2,595,271	284,244	12,395,509	9,515,994	2,595,271	284,244	12,395,509	
VMT	veh-mi/d				415,943,000				415,943,000	
No of Trips	no/d				82,808,879				82,808,879	
Diurnal	ton/d	14.8	34.1	20.4	69.3	32.2	38.6	21.9	92.7	23.4
Diurnal	g/d/unit	1.41	11.94	65.03	5.15	3.07	13.51	69.98	6.79	1.64
Diurnal Permeation	g/d/unit	1.00	5.48	50.08		2.64	6.82	54.50		
Running Loss	ton/d	7.7	66.2	49.0	122.9	8.3	67.6	50.1	126.0	3.1
Running Loss	g/mi	0.02	0.69	4.67	0.27	0.02	0.71	4.77	0.28	0.007
Running Loss Permeation	g/mi	0.001	0.020	0.547		0.002	0.024	0.584		
Hot Soak	ton/d	2.4	20.4	15.3	38.1	3.2	21.6	16.3	41.1	3.0
Hot Soak	g/trip	0.03	1.08	7.43	0.42	0.05	1.15	7.89	0.45	0.033
Hot Soak Permeation	g/trip	0.006	0.026	0.978		0.016	0.033	1.084		
Totals	ton/d	24.9	120.7	84.7	230.3	43.7	127.8	88.3	259.8	29.5

Attachment 2

EMFAC Technology Groups

Technology Group Definitions for EMFAC2000 and Corresponding Technology groups			
Old Group	Tech Group	Model Years Included	Emission Control Configurations, Fuel Metering Systems, And Applicable Emission Standards
1	1	Pre-1975	Without secondary air
2	2	Pre-1975	With secondary air
3	3	1975 and later	No catalyst
4	4	1975-1976	Oxidation catalyst, with secondary air
5	5	1975-1979	Oxidation catalyst without secondary air
	6	1980 and later	Oxidation catalyst without secondary air
6	7	1977 and later	Oxidation catalyst, with secondary air
7	8	1977-1979	Three-way catalyst with TBI/Carb
8 and 9	9	1981-1984	Three-way catalyst with TBI/Carb, 0.7 NOx
	10	1985 and later	Three-way catalyst with TBI/Carb, 0.7 NOx
10	11	1977-1980	Three-way catalyst with MPFI
11	12	1981-1985	Three-way catalyst with MPFI, 0.7 NOx
	13	1986 and later	Three-way catalyst with MPFI, 0.7 NOx
12	14	1981 and later	Three-way catalyst with TBI/Carb, 0.4 NOx
13	15	1981 and later	Three-way catalyst with MPFI, 0.4 NOx
14	16	1980 only	Three-way catalyst with TBI/Carb
15	17	1993 and later	Three-way catalyst with TBI/Carb, 0.25 HC
16	18	1993 and later	Three-way catalyst with MPFI, 0.25 HC
none	19	1996 and later	Three-way catalyst with TBI/Carb, 0.25 HC, and OBD II
none	20	1996 and later	Three-way catalyst with MPFI, 0.25 HC, and OBD II
none	21	1994-1995	Transitional Low Emission Vehicles (TLEV), **no** OBD II
none	22	1996 and later	TLEVs with OBD II
none	23	1996 and later	Low Emission Vehicles (LEV)
none	24	1996 and later	Ultra-Low Emission Vehicles (ULEV)
none	25	1996 and later	Zero Emission Vehicles (ZEV)
none	26	1996 and later	Three-way catalyst with TBI/Carb, 0.7 NOx, and OBD II
none	27	1996 and later	Three-way catalyst with MPFI, 0.7 NOx, and OBD II
none	28	All	Low Emission Vehicles (LEV II)
none	29	All	Ultra-Low Emission Vehicles (ULEV II)
none	30	All	Super Ultra-Low Emission Vehicles (SULEV)

TBI/Carb: Throttle-body injection or carburetor fuel metering system

MPFI: Multi point fuel injection system

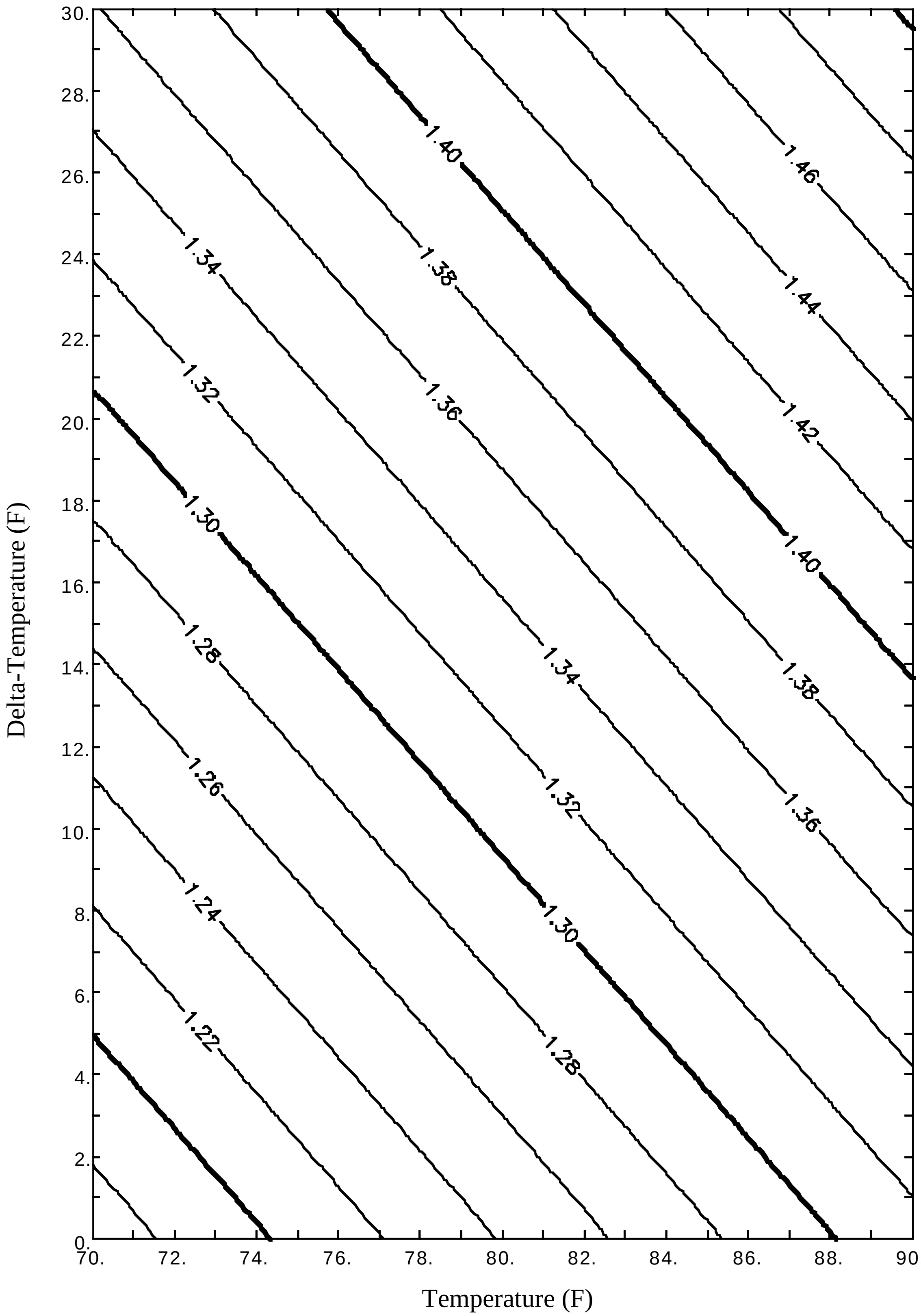
OBD II: Second generation on-board diagnostic systems. All 1996 and later vehicles (except Mexican vehicles) are assumed to be equipped with OBD II.

*Supergroups: (A) Non catalyst, (B) Oxidation catalyst, (C) Three-way catalysts with carburetors or throttle body injection, (D) Three-way catalysts with multi point fuel injection

Attachment 3

ETOH/MTBE Relationships for Diurnal and Resting Losses

Diurnal EtOH/MTBE versus Temperature and Delta-Temperature



Resting Loss EtOH/MTBE versus Temperature and Delta-Temperature