EMFAC Modeling Change Technical Memo

SUBJECT: INCREASED EVAPORATIVE EMISSIONS FROM ON-ROAD MOTOR VEHICLES DUE TO ETHANOL PERMEATION

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SUMMARY

The emission benefits for Phase 2 RFG were originally correlated to oxygen content and Reid Vapor Pressure (RVP) without regard to the oxygenating species. That is, a gasoline with 10% methyl t-butyl ether (MTBE) was assumed to be equivalent with respect to emissions to a gasoline with 5.7% ethanol (EtOH) because both fuels contained 2% oxygen. Recently completed testing shows that gasoline oxygenated with EtOH results in higher evaporative emissions compared to an MTBE-containing fuel with an equivalent vapor-pressure and oxygen content.

In the study sponsored by the Coordinating Research Council (CRC), the fuel systems of several vehicles were tested for diurnal evaporative permeation emissions with fuels containing either 10% MTBE or 5.7% EtOH. The results of this study were used as the basis for the proposed changes to the on-road emissions inventory.

Staff correlated the E65 diurnal data with temperature, and made separate correlations for normal and moderate emitters. Staff extended the diurnal results to the running loss and hot soak processes.

The emissions impact estimates for this change are shown below. The impacts for 2002 are zero because ethanol oxygenate was phased in between 2003 and 2004. The emissions increase for 2015 represents about 4% of the evaporative inventory. The emissions increase is mostly in the diurnal process.

Table 1
Summary of Emissions Changes due to Ethanol Permeation
Calendar Year 2002

Air Basin	Emission Changes by Pollutant, tons per day				
	HC	CO	NOx	CO_2	PM
Statewide	0.0	0.0	0.0	0.0	0.0
South Coast	0.0	0.0	0.0	0.0	0.0
San Joaquin Valley	0.0	0.0	0.0	0.0	0.0
Sacramento Valley	0.0	0.0	0.0	0.0	0.0
San Diego	0.0	0.0	0.0	0.0	0.0
San Francisco Bay Area	0.0	0.0	0.0	0.0	0.0

Table 2
Summary of Emissions Changes due to Ethanol Permeation
Calendar Year 2015

Air Basin	Emission Changes by Pollutant, tons per day				
	HC	CO	NOx	CO_2	PM
Statewide	14.0	0.0	0.0	0.0	0.0
South Coast	5.3	0.0	0.0	0.0	0.0
San Joaquin Valley	2.1	0.0	0.0	0.0	0.0
Sacramento Valley	1.8	0.0	0.0	0.0	0.0
San Diego	1.1	0.0	0.0	0.0	0.0
San Francisco Bay Area	2.2	0.0	0.0	0.0	0.0

NEED FOR REVISION

In response to an Executive Order issued by Governor Gray Davis, MTBE was phased out of all gasoline sold in California in 2003. The addition of ethanol to gasoline as a replacement for MTBE was required in 2004. Some refiners switched to ethanol oxygenate in 2003, the rest in 2004. EMFAC assumed the switch from MTBE to ethanol happened at once in 2004.

As a result, the fuel correction factors in EMFAC must be updated to reflect the impact that EtOH has on emissions, most notably, higher permeation rates through fuel tank walls, hoses, and fittings.

AFFECTED SOURCE CODE/VERSION

New algorithms to be added.

METHODOLOGY FOR REVISION

The Coordinating Research Council (CRC) sponsored a study (E65)[1] in which the fuel systems of several cars were tested for diurnal evaporative emissions on fuels containing either MTBE or EtOH. Although the test procedure was only designed to estimate the impact of EtOH for the diurnal heating process, staff also developed a methodology to adjust the emission inventory for the running loss and hot soak evaporative emission processes.

[1] Haskew, H., T. Liberty and D. McClement. 2004. Fuel Permeation from Automotive Systems. Final Report for CRC Project E-65. Coordinating Research Council, Alpharetta GA. Available at www.crcao.com/reports/recentstudies2004/E65 Final Report: 90204.pdf or www.arb.ca.gov/fuels/gasoline/permeation/090204finalrpt.pdf.

The proposed modifications will correct the evaporative emission rates in EMFAC to reflect the presence of EtOH. The development of process specific correction factors is proposed for this purpose. The form of the correction factor is given below.

$$ER_{etoh} = ER_{t,rvp} * (PERMfr * EtRFG2r + 1 - PERMfr) \quad \text{Eqn 1}$$

Where
- ER_{etoh} is the ethanol fuel emission rate expressed in grams per hour (g/hr)
- $ER_{t,rvp}$ is the MTBE emission rate expressed in g/hr, corrected for temperature and RVP (internal to EMFAC)
- **PERMfr** is the permeation fraction for each evaporative process (equation 3)
- **EtRFG2r** is the EtOH to MTBE ratio, as a function of temperature and emission regime (equation 2)

Ethanol-to-MTBE ratio (EtRFG2r)

EtRFG2r = diurnal rate on EtOH fuel ÷ diurnal rate on MTBE fuel **Eqn 2**

The ARB staff modeled the CRC E65 permeation study results as the ratio of diurnal emissions of ethanol-containing fuel to emissions of MTBE-containing fuel. For the 10 vehicles tested, the ratios of the 48 hourly diurnal emission rates for the EtOH and MTBE-containing fuels were analyzed.

In the E65 project, the fuel systems from 10 cars were removed from the chassis and subjected to normal diurnal tests. In a diurnal evaporative test the subject vehicle or system is placed in a temperature-controlled sealed chamber, the temperature of air in the chamber is slowly varied on a schedule, to simulate daily heating. During the test, the air in the enclosure is sampled periodically for gas-phase hydrocarbon concentration. The cumulative gas-phase inventory is calculated nominally at each hour as the concentration times volume, and differentiated to derive the hourly emission rates. These tests are normally done for multiples of 24 hours: 24 hours, 48 hours and 72 hours being most common.

For the E65 data, the only pattern that staff could discern from the diurnal permeation rate results was that two of the vehicles (5 and 6) had absolute emissions that were five to ten times higher than the others. However, these vehicles had much lower increases in emissions due to EtOH, resulting in lower ratios. A description of the vehicles tested in CRC E65 is presented in Table 3 below.

Table 3 – CRC E65 Test Fleet

Veh #	Vehicle Description	Veh #	Vehicle Description
1	2001 Tacoma Pickup	6	1993 Caprice
2	2000 Odyssey Van	7	1991 Accord
3	1999 Corolla	8	1989 Taurus
4	1997 Caravan Van	9	1985 Sentra
5	1995 Ranger Pickup	10	1978 Cutlass

Staff considered the results for Car 6 anomalous in that the diurnal emissions recorded for the MTBE fuel were higher than for EtOH fuel for the first 24-hour diurnal, but not for the second. For all the other vehicles tested, the EtOH results were consistently higher than the MTBE results. (See Figure 1).

In EMFAC, evaporative emissions are modeled utilizing three emission regimes. "**Normal**" emitting vehicles are defined as those that are generally free of defect and have emissions at or below their certification standard. "**Moderate**" emitters have some defect that can be detected through inspection or by the On-Board Diagnostic System (OBD) and emit at levels higher than the certification standard but less than vehicles with liquid leaks. As the name implies, "**liquid leakers**" are those vehicles that literally drip fuel. These vehicles are the evaporative equivalent to "Super Emitters" for exhaust.

Given EMFAC's structure, staff decided to group and analyze the CRC data in the following manner:

- 8 normal-emitting cars, 1, 2, 3, 4, 7, 8, 9 & 10,
- 2 moderate-emitting cars 5 and 6.
- The E65 study was designed to have no liquid leakers.

Separate ethanol-MTBE ratios were derived from data for normal and moderate emitters. We assumed a small, non-unity ratio (1.05) for liquid leakers. For vehicle 6, the moderate vehicle with the anomalous MTBE results, the day-2 results for both MTBE and EtOH were also used for day 1.

For each group of vehicles all of the hour-by-hour ethanol-to-MTBE ratios were plotted versus temperature, and were found to be statistically not significant. Therefore, the mean values were used. The results of the linear regression analysis are shown in Table 4 below. Scatter plots for the normal and the moderate emitters are shown in Figures 2 and 3. The final recommended values for EtRFG2r are shown in Table 5.

Table 4 – Linear Regression Statistics for E65 diurnal ratios

	Best fit Slope	Intercept	p-statistic on slope	Mean	Standard deviation
	per degree F				
Normals	0.0097	1.695	0.133	2.55	1.58
Moderates	0.0006	1.151	0.787	1.20	0.24
Liquid Leakers				1.05*	

*Assumed number

Table 5—Ethanol-to-MTBE ratio values

Normals	2.55
Moderates	1.20
Liquid Leakers	1.05

Permeation Fraction (PERMfr)

The CRC E65 study was only designed to investigate the emission effects of permeation. No liquid leaks were present in the vehicle sample. Vapor losses were excluded from the diurnal results by venting the vapor storage canisters outside of the test enclosure. Therefore, the ethanol increases described above are only applicable to that part of the diurnal emissions attributable to permeation.

To determine this fraction, staff assumed that resting losses were a reasonable approximation for permeation. Resting losses are those evaporative emissions that occur when the engine is not running and the ambient temperature is falling or stable. The ratio of resting loss to the diurnal emissions would approximate the fraction of permeation for the diurnal heating process. This ratio was corrected by a factor of 90% in recognition that not all resting losses would be attributable to permeation.

$$\mathbf{PERMfr = 0.9 * ER_{resting} * RVPTCF / (ER_{process} * RVPTCF)} \qquad \textbf{Eqn 3}$$

Where

PERMfr is the permeation fraction

$ER_{resting}$ is the emission rate for evaporative resting loss in g/h, as a function of temperature, tech group, and emission regime (internal to EMFAC)

RVPTCF is the vapor pressure and temperature correction factor (internal to EMFAC)

$ER_{process}$ is the emission rate for the particular evaporative process expressed in g/h (internal to EMFAC)

0.9 is the fraction of resting loss assumed to be attributable to permeation

Application by Process

Diurnal/Resting Permeation Fraction

The ratio was calculated using the relationship between resting loss and diurnal emissions as a function of temperature as estimated by EMFAC. Figure 4 illustrates the diurnal emission rate *vs* temperature, 90% of resting loss *vs* temperature, and their ratio for 79-94 model year fuel-injected cars using the 65-110°F correlation.

Running Loss Permeation Fraction

As with diurnal emissions, staff assumed that resting loss was a reasonable surrogate for permeation. Therefore, the ratio of resting losses expressed in grams per hour, to running loss expressed in those units would be used to approximate the permeation fraction for running loss.

The running loss correlations for the different technology groups give the cumulative emissions as a function of time, corrected to a given ambient temperature. To compare with the resting losses, which are correlated as grams per hour at a given hour's ambient temperature, the running loss correlations must be differentiated with time. The value for 15 minutes (weighted average trip length) was chosen to calculate the permeation fraction.

Hot Soak Permeation Fraction

As with the other evaporative processes, the permeation fraction for hot soak is calculated as the ratio of resting losses in grams per hour to hot soak emissions in those units. EMFAC models hot-soak emissions as a function of ambient temperature and fuel volatility (RVP). The correlations give the hot soak emissions for a 35-minute period. This was converted to a 1-hour basis for comparison with the resting loss correlation, which is in grams per hour for a given hourly ambient temperature.

Application by Technology Group

The resting loss basic emission rates and corrections are given in EMFAC as a function of technology group, aspiration technology, and model year. Likewise, the BERs for running loss are given as functions of these parameters, but often in different model year ranges, or subdivided by truck or car. For this reason, Table 6 was developed to display the combinations of technology groupings that were used, and the extension of the combinations to evaporative technology groups in EMFAC.

Table 6—Evap Tech group assignments

	Table 5.1-3*			Table 5.3-2a*		Table 5.2-4*	
EMFAC2002 Tech Group Mapping	Vehicle Type	Running Loss Grouping		Diurnal/Resting Grouping		Hot Soak Grouping	
1, 21	Car/Truck	Carb	Pre-1970				
2, 3	Car	Carb	1970-76	CARB	Pre-77	CARB	Pre-77
4, 5	Car	Carb	1977+	CARB	77+	CARB	77+
6, 7, 8, 9, 10, 11, 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
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

* Table numbers refer to coefficients in the EMFAC 2000 Technical Support Document.
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 (pre-79, 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.

Permeation Fraction Correlations

The resulting running loss and hot soak permeation fractions were calculated from the BER correlations and correction factors in the EMFAC 2000 Technical Support Document for the tech group combinations, and for the regimes of normal, moderate, and liquid leaker. The calculations were done for the range of 65 to 110°F, and then fitted to a 2, 3, or 4-power polynomial. An example of the calculated data and the polynomial fit is shown in Figure 5. These coefficient results are displayed for the hot soak process in Table 7. These coefficient results are displayed in Tables 8a and 8b for the running loss process.

In keeping with the previous EMFAC protocol, the liquid leaker correlations for running loss and hot soak were not temperature-corrected.

Table 5—Hot Soak Permeation Fraction Correlations

			Coefficients for Hot Soak Permeation Factor Correlations					Domain Restrictions			
Tech Groups	Fuel sys/ Model yr	Regime	A	B	C	D	E	Lower		Upper	
Car TGs 1, 21	Carb 77-	Normal	6.7473E-08	-2.7737E-05	4.1488E-03	-2.5670E-01	5.6790E+00	T < 65	PF = 0.110	None	
Truck TGs 22, 23		Moderate		-1.4121E-06	3.8110E-04	-3.0577E-02	8.0438E-01	T < 65	PF = 0.041	None	
		High	-3.3470E-08	1.2209E-05	-1.5761E-03	8.8644E-02	-1.8020E+00	T < 65	PF = 0.055	None	
Car TGs 4, 5	Carb 77+	Normal		-6.4757E-06	1.7765E-03	-1.4672E-01	3.9217E+00	T < 65	PF = 0.118	None	
Truck TGs 24, 25		Moderate	-8.5461E-08	3.1508E-05	-4.1687E-03	2.3742E-01	-4.9149E+00	T < 65	PF = 0.031	None	
		High	-3.3470E-08	1.2209E-05	-1.5761E-03	8.8644E-02	-1.8020E+00	T < 65	PF = 0.055	None	
Car TGs 6, 7, 8, 9, 10, 11, 12, 13	FI 86+	Normal		-6.0616E-06	1.3658E-03	-9.5670E-02	2.4026E+00	T < 65	PF = 0.29	None	
Truck TGs 26, 27, 28, 29, 30, 31, 32, 33		Moderate		-1.7869E-06	4.6374E-04	-3.7838E-02	1.0082E+00	T < 65	PF = 0.017	T >110	PF = 0.08
		High	-3.3470E-08	1.2209E-05	-1.5761E-03	8.8644E-02	-1.8020E+00	T < 65	PF = 0.055	None	
Car TG 14	FI Enhanced Evap	Normal		-2.3621E-06	5.3395E-04	-3.7670E-02	9.5892E-01	T < 65	PF = 0.117	None	
Truck TG 34		Moderate		-6.8803E-07	1.7862E-04	-1.4585E-02	3.8929E-01	T < 65	PF = 0.007	T >110	PF=0.0309
		High	-3.3470E-08	1.2209E-05	-1.5761E-03	8.8644E-02	-1.8020E+00	T < 65	PF = 0.055	None	
Car TGs 15, 17	FI Zero Evap	Normal		-2.2394E-06	5.0155E-04	-3.4570E-02	8.3653E-01	T < 65	PF = 0.094	None	
Truck TGs 35, 37		Moderate		-6.5466E-07	1.7002E-04	-1.3899E-02	3.7240E-01	T < 65	PF = 0.0075	T >110	PF = 0.0298
		High	-3.3470E-08	1.2209E-05	-1.5761E-03	8.8644E-02	-1.8020E+00	T < 65	PF = 0.055	None	

Perm Fract = $AT^4 + BT^3 + CT^2 + DT + E$, T in deg F

Table 6a—Running Loss Permeation Fraction Correlations (Cars)

	Tech Groups	Fuel sys/ Model yr	Regime	Coefficients for Running Loss Permeation Factor Correlations A	B	C	D	E	Domain Restrictions	
Car	TGs 1, 21	Carb 70-	Normal			1.8484E-06	-7.9614E-06	-5.7824E-03	T < 65	PF = 0.0018
			Moderate	6.3154E-09	-2.3204E-06	3.2294E-04	-1.9308E-02	4.2001E-01	T < 65	PF = 0.005
			High	-2.7377E-09	9.9867E-07	-1.2892E-04	7.2506E-03	-1.4740E-01	T < 65	PF = 0.0045
Car	TGs 2, 3	Carb 70 to 76	Normal	2.8825E-08	-1.0798E-05	1.5371E-03	-9.4311E-02	2.1034E+00	T < 65	PF = 0.0171
			Moderate	6.3154E-09	-2.3204E-06	3.2294E-04	-1.9308E-02	4.2001E-01	T < 65	PF = 0.005
			High	-2.7377E-09	9.9867E-07	-1.2892E-04	7.2506E-03	-1.4740E-01	T < 65	PF = 0.0045
Car	TGs 4, 5	Carb 77+	Normal	2.8825E-08	-1.0798E-05	1.5371E-03	-9.4311E-02	2.1034E+00	T < 65	PF = 0.0171
			Moderate	-9.9622E-09	4.3594E-06	-6.3898E-04	3.9126E-02	-8.5796E-01	T < 65	PF = 0.005
			High	-2.7377E-09	9.9867E-07	-1.2892E-04	7.2506E-03	-1.4740E-01	T < 65	PF = 0.0045
Car	TGs 6, 7, 8, 9, 10, 11, 12, 13	FI 79-94 Pre Enh Evap	Normal	6.4222E-08	-2.3513E-05	3.2308E-03	-1.9200E-01	4.1642E+00	T < 65	PF = 0.025
			Moderate		5.6941E-07	-3.5135E-05	-2.5610E-03	1.6367E-01	T < 65	PF = 0.004
			High	-3.3608E-08	1.2260E-05	-1.5826E-03	8.9008E-02	-1.8095E+00	T < 65	PF = 0.055
Car	TG 14	FI Enhanced Evap	Normal	1.9152E-08	-7.0046E-06	9.6131E-04	-5.7057E-02	1.2362E+00	T < 65	PF = 0.008
			Moderate		1.6045E-07	-8.1202E-06	-9.6472E-04	5.4652E-02	T < 65	PF = 0.0016
			High	-3.3608E-08	1.2260E-05	-1.5826E-03	8.9008E-02	-1.8095E+00	T < 65	PF = 0.055
Car	TGs 15, 17	FI Zero Evap	Normal	4.7080E-09	-1.7295E-06	2.3851E-04	-1.4230E-02	3.0975E-01	T < 65	PF = 0.0016
			Moderate		4.1347E-08	-2.3857E-06	-2.0622E-04	1.2600E-02	T < 65	PF = 0.0005
			High	-3.3608E-08	1.2260E-05	-1.5826E-03	8.9008E-02	-1.8095E+00	T < 65	PF = 0.055

Perm Fract = $AT^4 + BT^3 + CT^2 + DT + E$, T in deg F

Table 6b—Running Loss Permeation Fraction Correlations (Trucks)

	Tech Groups	Fuel sys/ Model yr	Regime	Coefficients for Running Loss Permeation Factor Correlations A	B	C	D	E	Domain Restrictions	
Truck	TGs 22, 23	Carb <80	Normal		-2.9348E-07	9.1217E-05	-5.8658E-03	9.4318E-02	T < 65	PF = 0.0202
			Moderate		-2.4910E-07	8.1519E-05	-6.6678E-03	1.6753E-01	T < 65	PF = 0.0111
			High	-1.1928E-08	4.3511E-06	-5.6168E-04	3.1590E-02	-6.4220E-01	T < 65	PF = 0.0196
Truck	TGs 24, 25	Carb 80+	Normal	2.8017E-08	-1.0538E-05	1.5099E-03	-9.3176E-02	2.0883E+00	T < 65	PF = 0.0175
			Moderate	-1.8457E-08	7.3542E-06	-1.0277E-03	6.1230E-02	-1.3207E+00	T < 65	PF = 0.0078
			High	-1.1928E-08	4.3511E-06	-5.6168E-04	3.1590E-02	-6.4220E-01	T < 65	PF = 0.0196
Truck	TGs 26, 27, 28, 29, 30, 31, 32, 33	FI Pre Enhanced Evap	Normal	1.5571E-07	-5.6665E-05	7.7217E-03	-4.5527E-01	9.8043E+00	T < 65	PF = 0.056
			Moderate		5.6941E-07	-3.5135E-05	-2.5610E-03	1.6367E-01	T < 65	PF = 0.004
			High	-3.3608E-08	1.2260E-05	-1.5826E-03	8.9008E-02	-1.8095E+00	T < 65	PF = 0.055
Truck	TG 34	FI Enhanced Evap	Normal	2.0730E-08	-7.5358E-06	1.0257E-03	-6.0399E-02	1.2993E+00	T < 65	PF = 0.0077
			Moderate		5.5117E-08	-3.8226E-06	-2.0171E-04	1.4634E-02	T < 65	PF = 0.0005
			High	-3.3608E-08	1.2260E-05	-1.5826E-03	8.9008E-02	-1.8095E+00	T < 65	PF = 0.055
Truck	TGs 35, 37	FI Zero Evap	Normal		4.0267E-07	-1.1020E-04	1.0153E-02	-2.9912E-01	T < 65	PF = 0.0066
			Moderate	1.9049E-09	-6.8289E-07	9.2052E-05	-5.3665E-03	1.1527E-01	T < 65	PF = 0.0019
			High	-3.3608E-08	1.2260E-05	-1.5826E-03	8.9008E-02	-1.8095E+00	T < 65	PF = 0.055

Perm Fract = $AT^4 + BT^3 + CT^2 + DT + E$, T in deg F

INVENTORY EFFECTS

The estimates of the effect of adding the ethanol permeation routine to the program are given below for the scenario years of 2002, 2005, 2010, 2015, and 2020 for the State as a whole and for the South Coast, San Joaquin Valley, Sacramento Valley, San Diego, and San Francisco Bay areas. (Tables 9 to 13).

Table 14 shows a detail emission analysis for the South Coast Basin, 2005.

No effects are shown for 2002 because the ethanol phase-in happened in 2003 and 2004.

In general most of the effects were due to the diurnal and resting loss process.

The effects are much smaller in the future years because the absolute magnitude of the evaporative emissions tends more to cleaner technologies (near-zero- and zero-evap cars).

In 2005, the estimated statewide increase of 28 tpd represents 6% of the evaporative inventory.

Table 9
Summary of Emissions Changes due to Ethanol Permeation
Calendar Year 2002

Air Basin	Emission Changes by Pollutant, tons per day				
	HC	CO	NOx	CO_2	PM
Statewide	0.0	0.0	0.0	0.0	0.0
South Coast	0.0	0.0	0.0	0.0	0.0
San Joaquin Valley	0.0	0.0	0.0	0.0	0.0
Sacramento Valley	0.0	0.0	0.0	0.0	0.0
San Diego	0.0	0.0	0.0	0.0	0.0
San Francisco Bay Area	0.0	0.0	0.0	0.0	0.0

Table 10
Summary of Emissions Changes due to Ethanol Permeation
Calendar Year 2005

Air Basin	Emission Changes by Pollutant, tons per day				
	HC	CO	NOx	CO_2	PM
Statewide	28.4	0.0	0.0	0.0	0.0
South Coast	11.6	0.0	0.0	-0.1	0.0
San Joaquin Valley	4.1	0.0	0.0	0.0	0.0
Sacramento Valley	3.5	0.0	0.0	0.0	0.0
San Diego	2.2	0.0	0.0	0.0	0.0
San Francisco Bay Area	4.4	0.0	0.0	0.0	0.0

Table 11
Summary of Emissions Changes due to Ethanol Permeation
Calendar Year 2010

Air Basin	Emission Changes by Pollutant, tons per day				
	HC	CO	NOx	CO_2	PM
Statewide	20.1	0.1	0.0	0.1	0.0
South Coast	7.8	0.0	0.0	0.0	0.0
San Joaquin Valley	3.0	0.0	0.0	0.0	0.0
Sacramento Valley	2.6	0.0	0.0	0.0	0.0
San Diego	1.5	0.0	0.0	0.0	0.0
San Francisco Bay Area	3.2	0.0	0.0	0.0	0.0

Table 12
Summary of Emissions Changes due to Ethanol Permeation
Calendar Year 2015

Air Basin	Emission Changes by Pollutant, tons per day				
	HC	CO	NOx	CO_2	PM
Statewide	14.0	0.0	0.0	0.0	0.0
South Coast	5.3	0.0	0.0	0.0	0.0
San Joaquin Valley	2.1	0.0	0.0	0.0	0.0
Sacramento Valley	1.8	0.0	0.0	0.0	0.0
San Diego	1.1	0.0	0.0	0.0	0.0
San Francisco Bay Area	2.2	0.0	0.0	0.0	0.0

Table 13
Summary of Emissions Changes due to Ethanol Permeation
Calendar Year 2020

Air Basin	Emission Changes by Pollutant, tons per day				
	HC	CO	NOx	CO_2	PM
Statewide	10.1	0.0	0.0	-0.1	0.0
South Coast	3.8	0.0	0.0	0.0	0.0
San Joaquin Valley	1.5	0.0	0.0	0.0	0.0
Sacramento Valley	1.2	0.0	0.0	0.0	0.0
San Diego	0.8	0.0	0.0	0.0	0.0
San Francisco Bay Area	1.5	0.0	0.0	0.0	0.0

Table 14
Ethanol Permeation Inventory Effects
SCAB, 2005, Summer Ozone Temperatures

		Ph 2 Gaso/MTBE				Ph 2 Gaso/EtOH				Increase
		Normals	Moderates	Liq Lkrs	Total	Normals	Moderates	Liq Lkrs	Total	
No of Vehicles		9,374,636	2,556,719	280,022	12,211,376	9,374,636	2,556,719	280,022	12,211,376	
VMT	veh-mi/d				411,299,000				411,299,000	
No of Trips	no/d				81,702,000				81,702,000	
Diurnal	ton/d	8.4	15.7	13.1	37.3	15.9	16.8	13.9	46.6	9.3
Diurnal	g/d/unit	0.82	5.58	42.62	2.77	1.54	5.97	45.17	3.47	0.69
Diurnal Permeation	g/d/unit	0.44	1.40	33.84	1.41	1.15	1.71	36.22	2.08	0.67
Running Loss	ton/d	6.7	64.6	43.2	114.5	7.3	64.9	43.5	115.7	1.2
Running Loss	g/mi	0.02	0.68	4.16	0.25	0.02	0.68	4.18	0.26	0.003
Running Loss Permeation	g/mi	0.001	0.013	0.301	0.011	0.003	0.016	0.316	0.013	0.002
Hot Soak	ton/d	1.5	14.5	9.8	25.8	2.4	14.5	9.9	26.8	1.0
Hot Soak	g/trip	0.02	0.77	4.76	0.29	0.03	0.77	4.77	0.30	0.011
Hot Soak Permeation	g/trip	0.008	0.024	0.328	0.019	0.021	0.029	0.344	0.030	0.011
Totals	ton/d	16.7	94.7	66.2	177.6	25.6	96.3	67.2	189.1	11.5

Figure 1
E65 Diurnal Permeation Results, Car 6

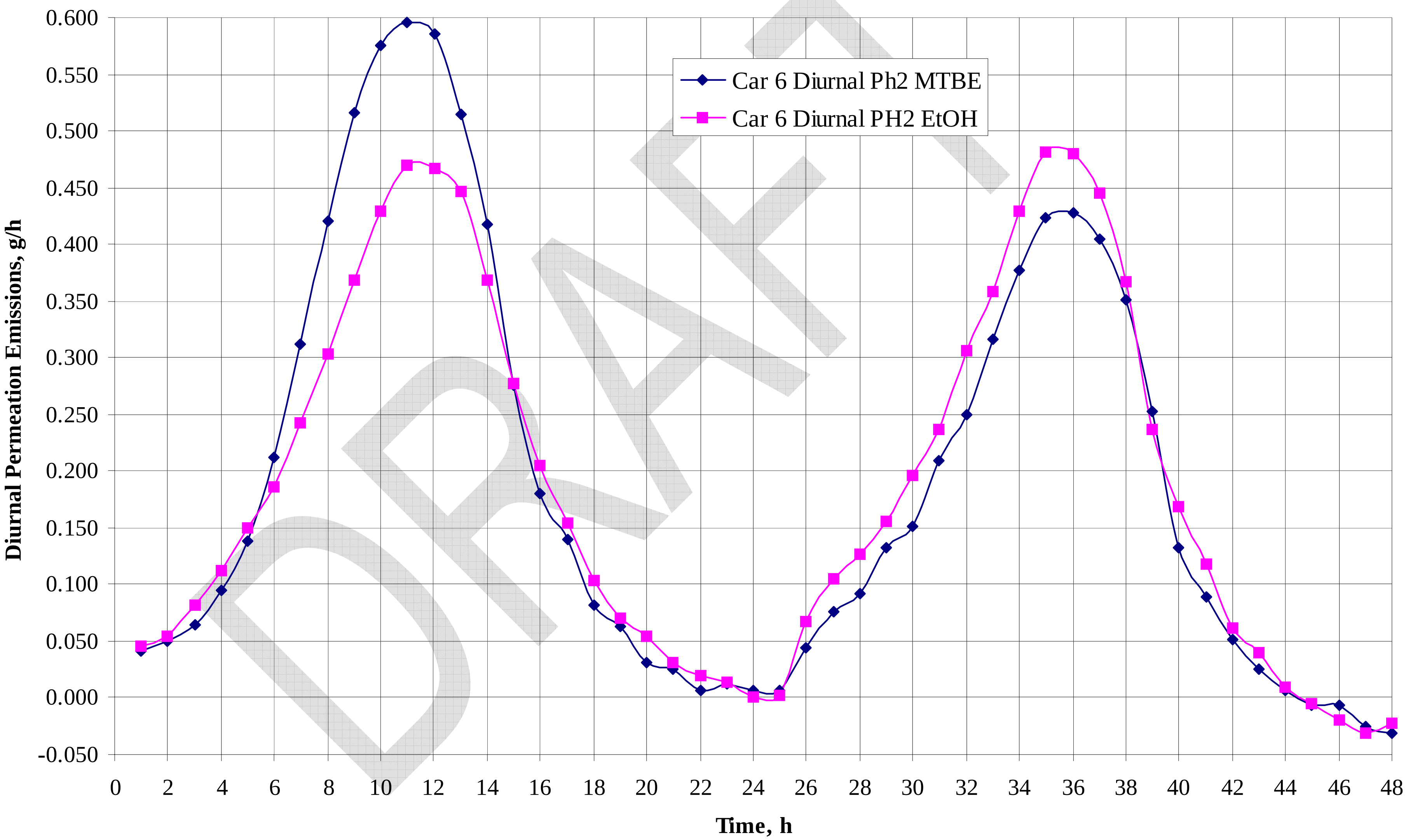
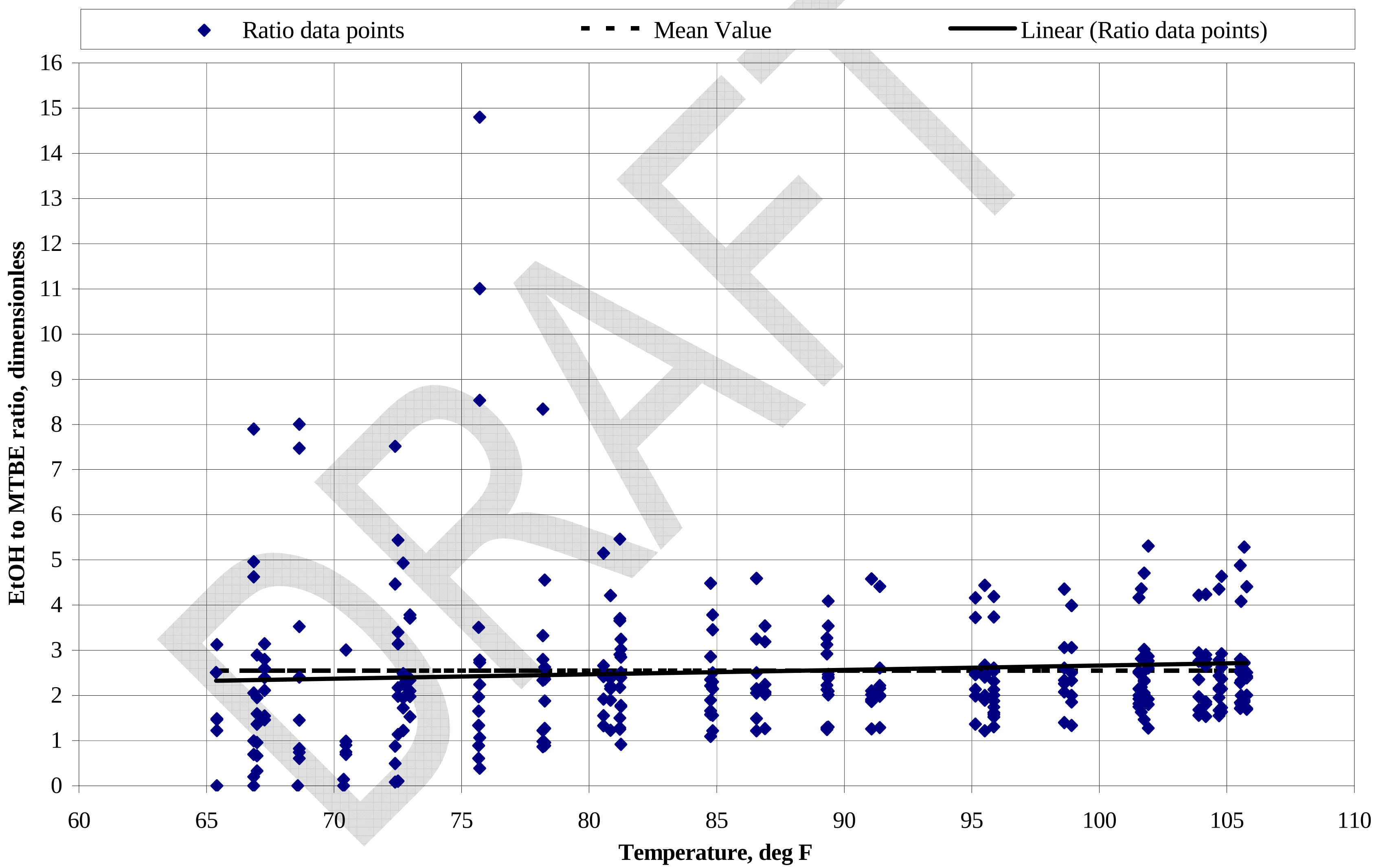


Figure 2
E65 Diurnal Augmentation Ratios, Normals



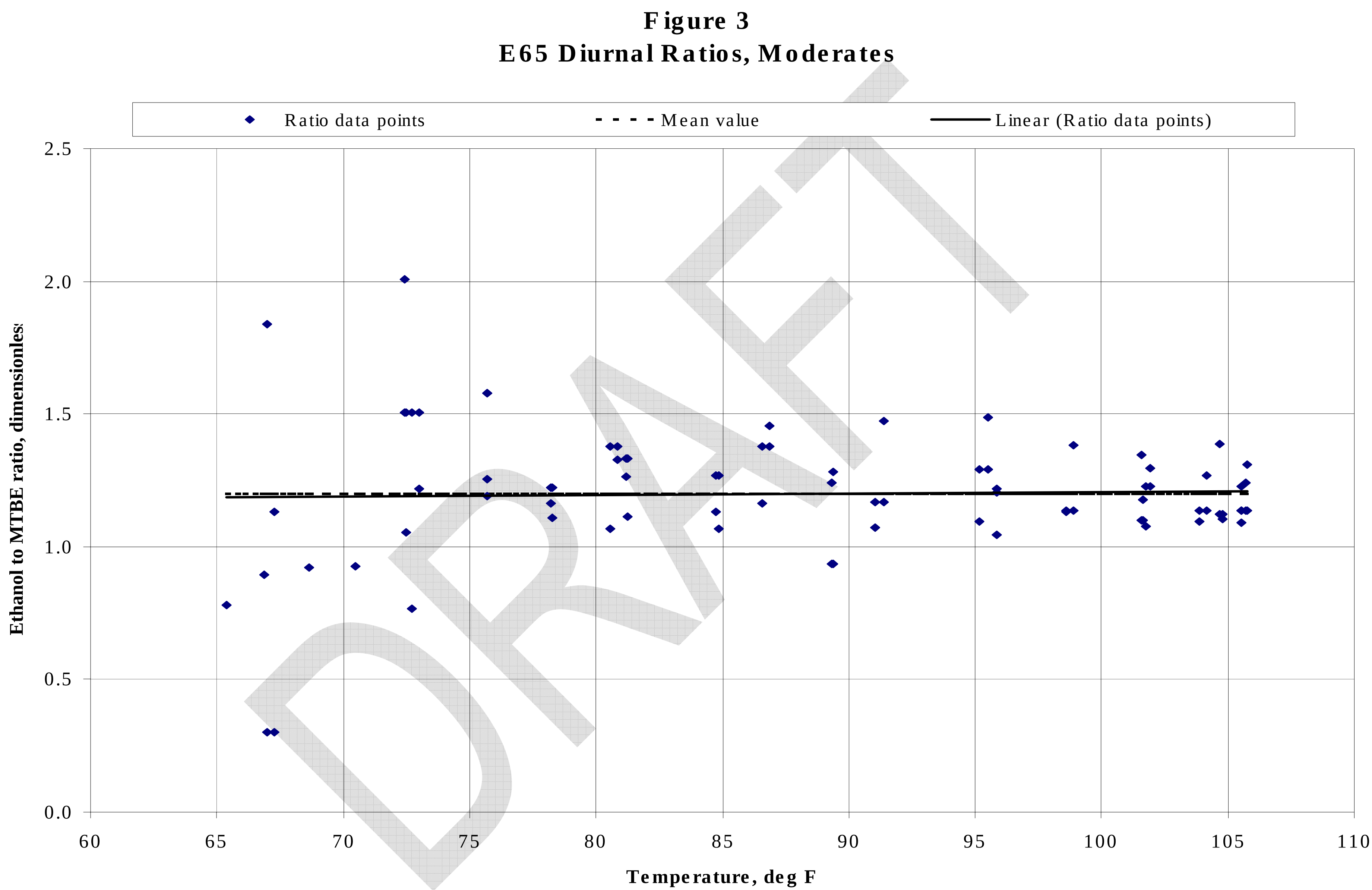


Figure 3
E65 Diurnal Ratios, Moderates
Ratio data points
Mean value
Linear (Ratio data points)
2.5
2.0
1.5
1.0
0.5
0.0
60
65
70
75
80
85
90
95
100
105
110
Temperature, deg F
Ethanol to MTBE ratio, dimensionless
DRAFT

Figure 4
Diurnal Permeation Fraction
Example, 79-94 Fuel Injected

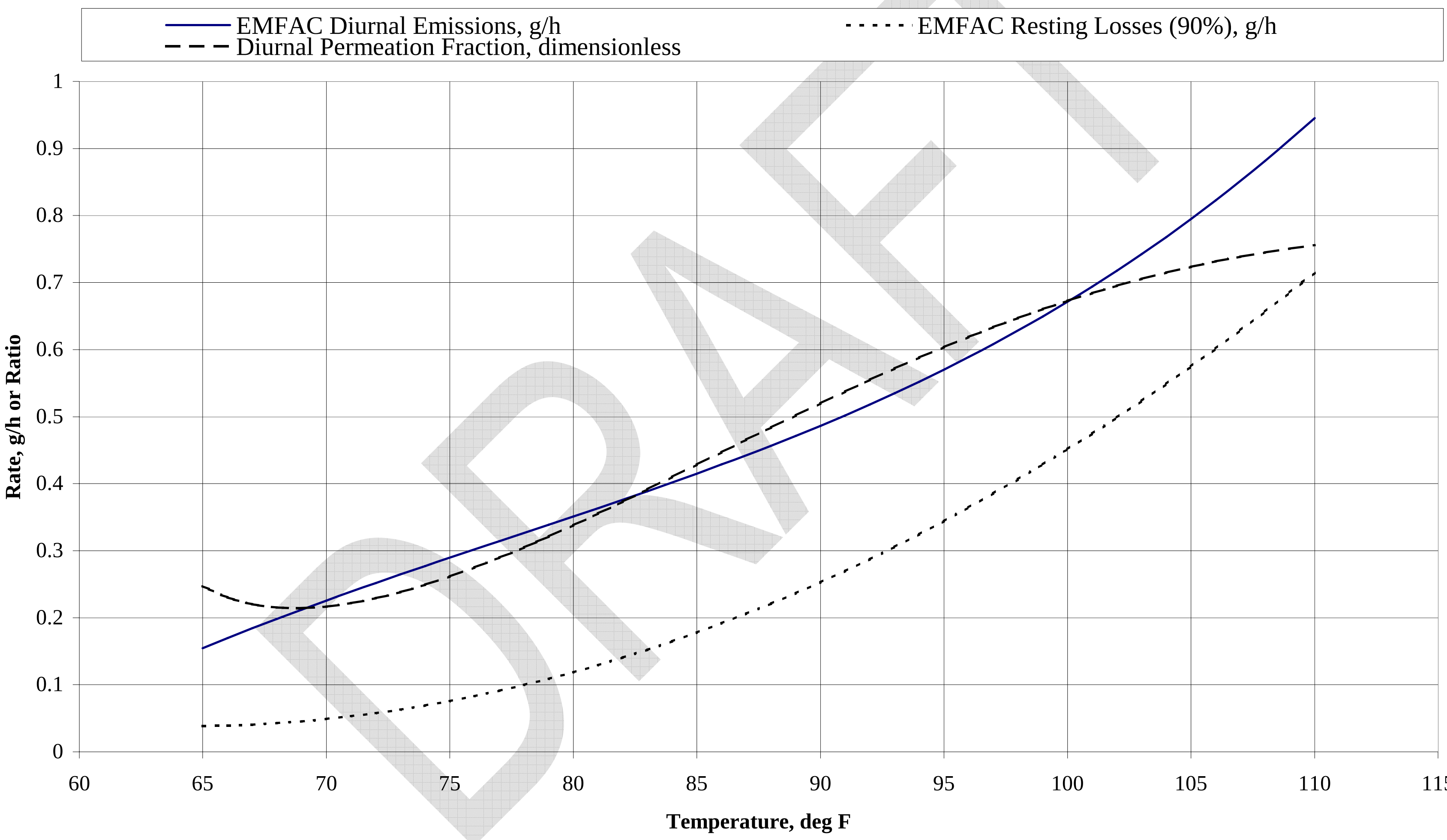
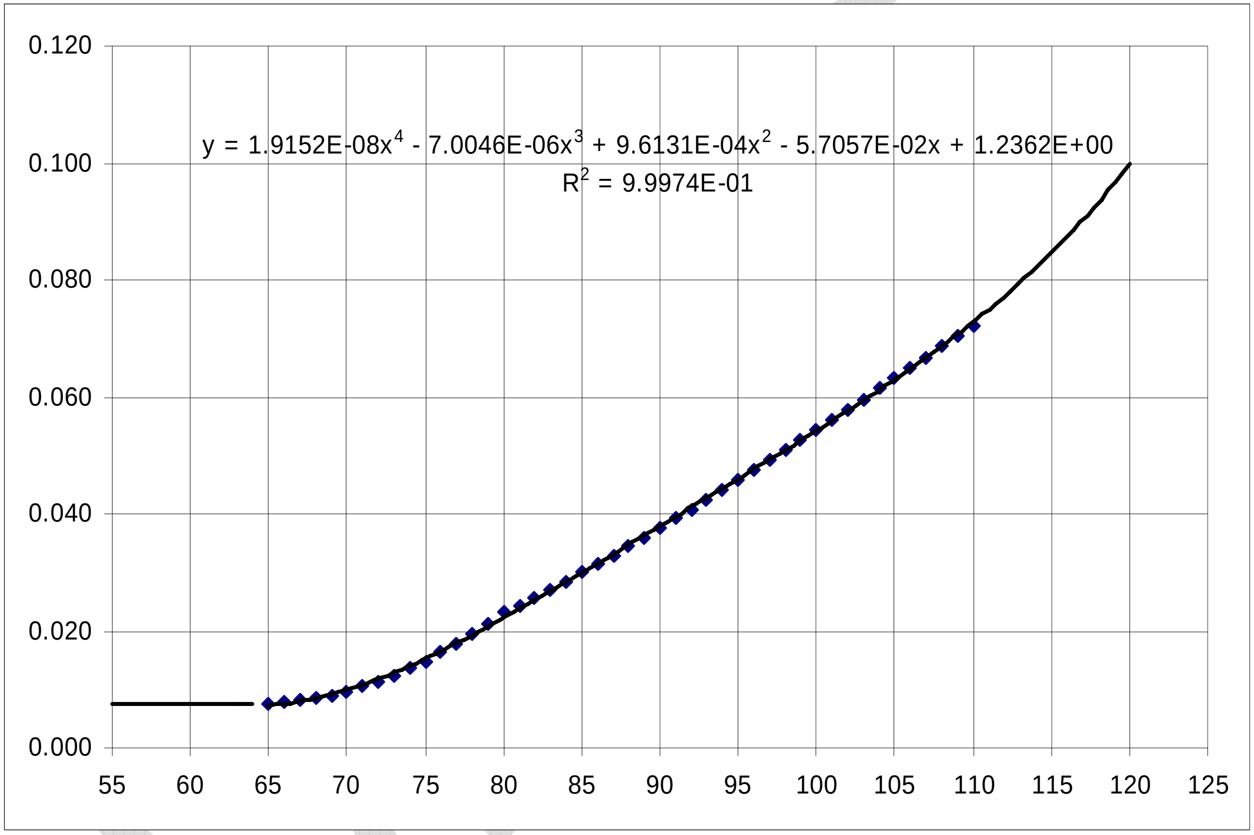


Figure 5
Running Loss Permeation Fraction Example
Car Enhanced Evap Normal



Note: Constant 0.008 value below 65°F.