EMFAC Modeling Change Technical Memo

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

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SUMMARY

In EMFAC 2002, the emission benefits for Phase 2 RFG were 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.

Recent testing sponsored by the Coordinating Research Council (CRC) 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 CRC E65 study the fuel systems of several vehicles were removed and their diurnal evaporative permeation emissions measured with fuels containing either 10% MTBE or 5.7% EtOH. The results of this study are reflected in EMFAC 2007, the update to EMFAC 2002.

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 estimates for this change are shown below. As shown in Table 1, the impacts for 2002 are zero because ethanol oxygenate was phased in between 2003 and 2004. As shown in Table 2, 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				
	ROG	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				
	ROG	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 Executive Order D-5-99 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. Because of the difficulty of tracking these individual formulation changes, 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 removed and tested for diurnal evaporative emissions using Phase 2 reformulated gasoline (RFG2) containing either MTBE or EtOH. Although the test procedure was only designed to estimate the impact of EtOH for the diurnal heating process, ARB 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

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) **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 RFG2 to emissions of MTBE-containing RFG2. 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, and the temperature of air in the chamber is slowly varied, to mimic changes in ambient temperature typical of an average summer day or other day. 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 hydrocarbon (HC) 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.

A description of the vehicles tested in CRC E65 is presented in Table 3 below. They were distributed in age like the South Coast vehicle population. (One particular model year vehicle to represent a decile of the population of that age range.)

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www.crcao.com/reports/recentstudies2004/E65 Final Report: 90204.pdf or
www.arb.ca.gov/fuels/gasoline/permeation/090204finalrpt.pdf.

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

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. 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, moderate and liquid leaker. "**Normal**" emitting vehicles are defined as those that are generally free of defect and have HC 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 the CRC data into these three emission regimes. Based on analysis of the E65 data, the ten vehicles were binned as follows:

- 8 normal-emitting vehicles, 1, 2, 3, 4, 7, 8, 9 & 10,
- 2 moderate-emitting vehicle 5 and 6.
- 0 liquid leakers (reflects study design).

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

All of the hour-by-hour ethanol-to-MTBE ratios were plotted versus temperature. Scatter plots for the normal and the moderate emitters are shown in Figures 2 and 3.Therefore, the mean values were used. The results of the linear regression analysis are shown in Table 4 below. The final recommended values for EtRFG2r are shown in Table 5..

Figure 1
E65 Diurnal Permeation Results, Car 6

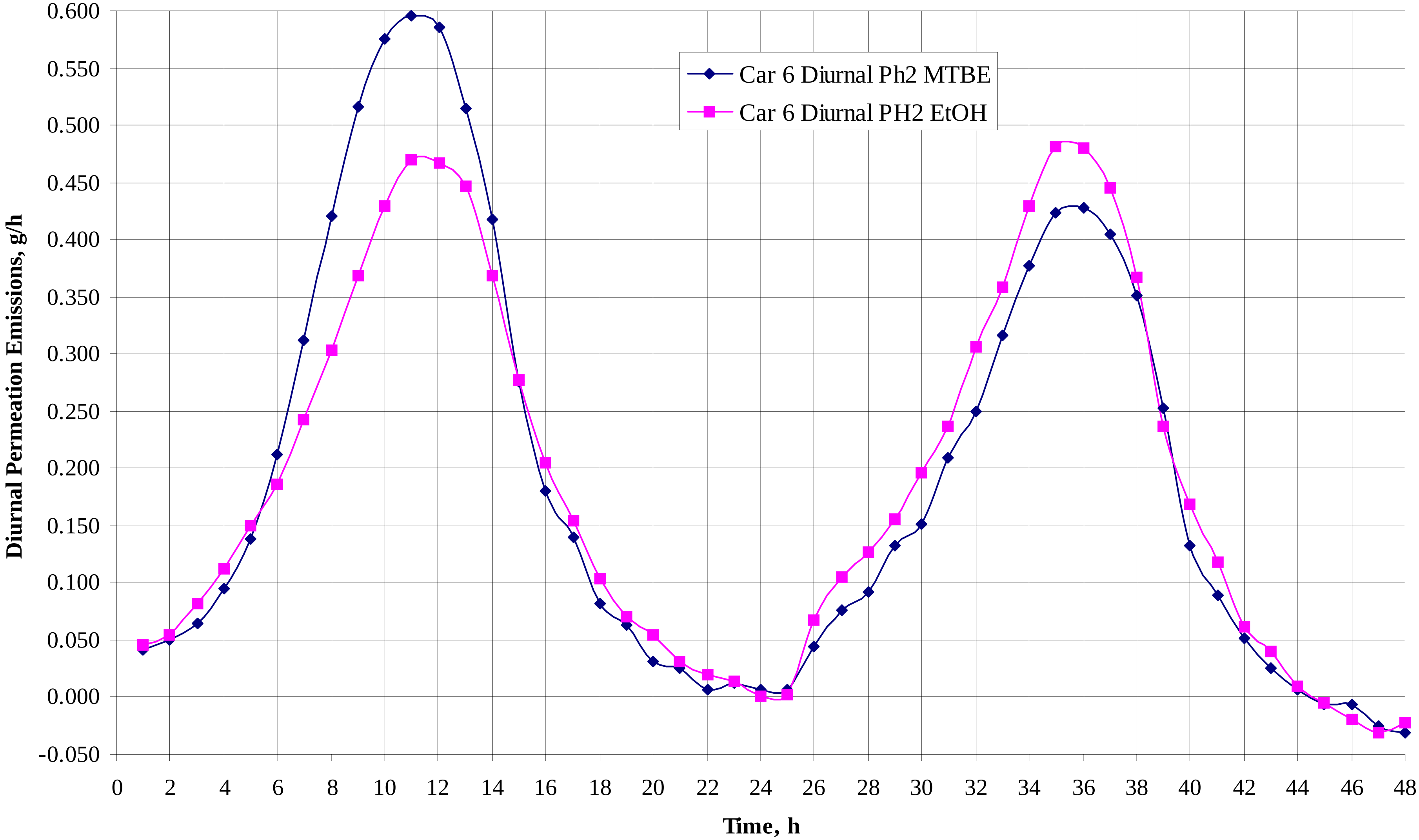


Figure 2
E65 Diurnal Augmentation Ratios, Normals

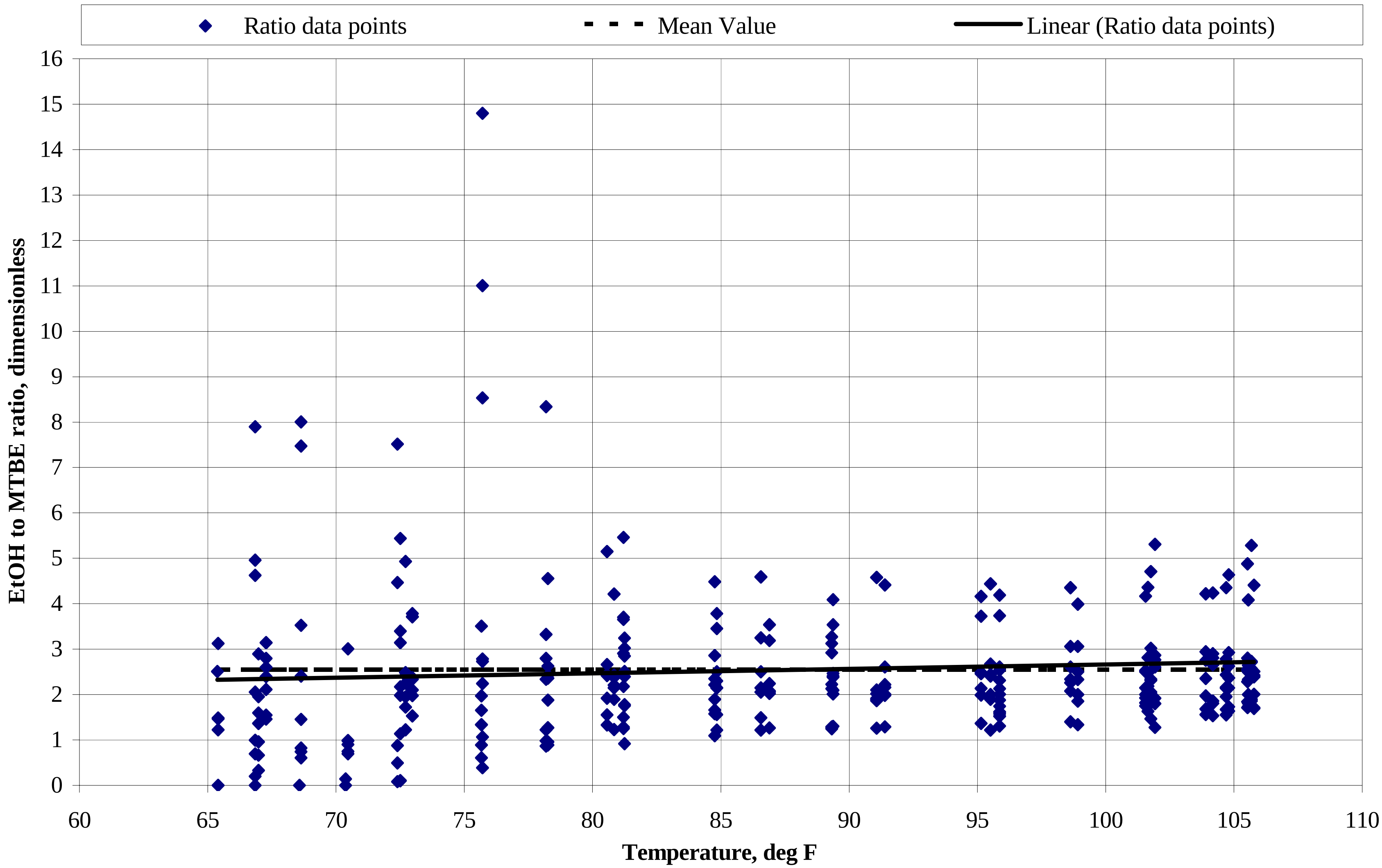


Figure 3
E65 Diurnal Ratios, Moderates

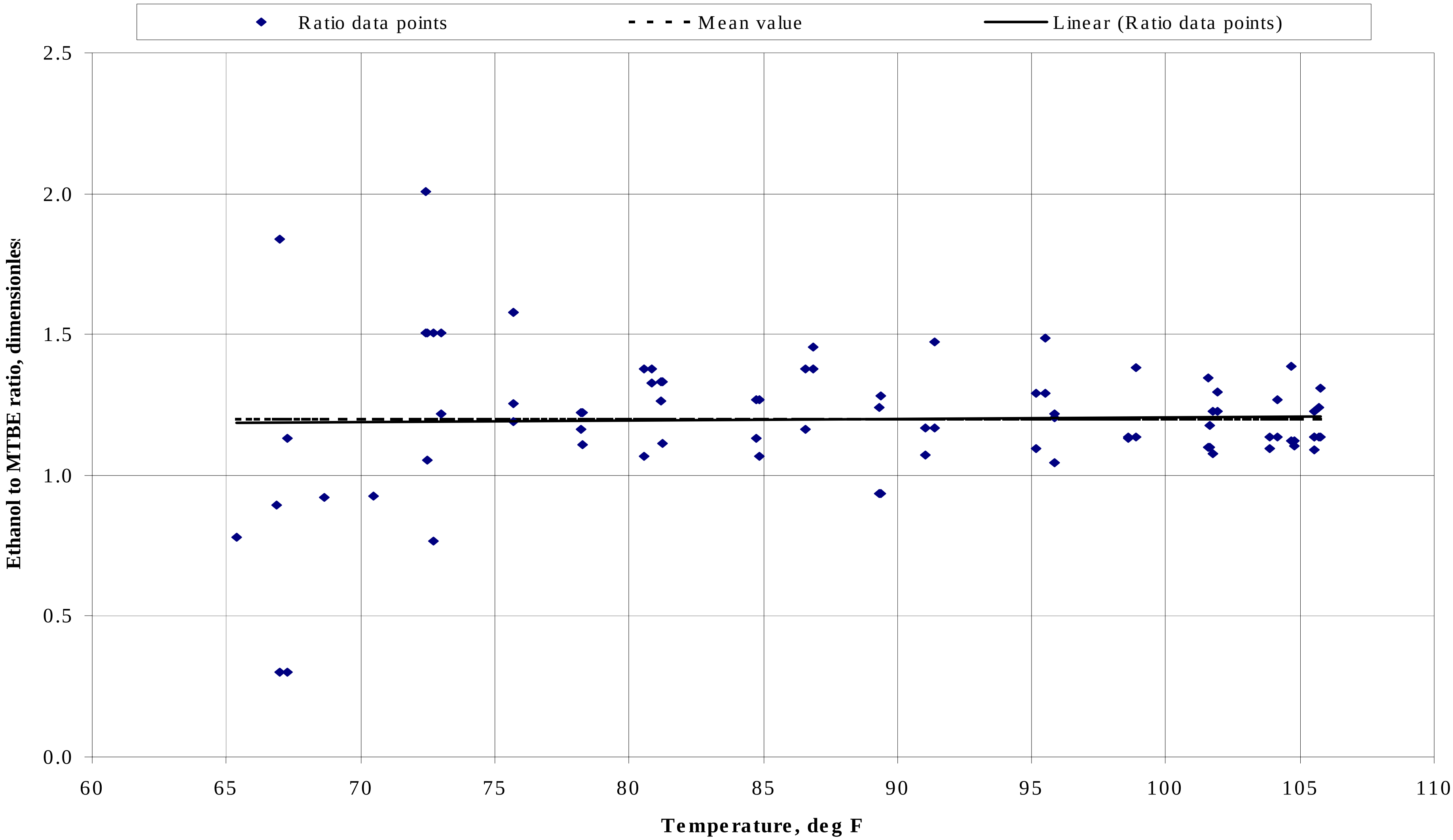


Table 4 – Linear Regression Statistics for E65 diurnal Augmentation Ratios

	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—Augmentation ratio values

Emitter Category	Ratio	Absolute Permeation MTBE fuel*	Absolute Permeation Ethanol Fuel*
		g/h	g/h
Normals	2.55	0.44	1.15
Moderates	1.20	1.4	1.7
Liquid Leakers	1.05	33.8	36.2

* Values for 2005 fleet EMFAC 2002 Default Temperatures

<u>Permeation Fraction (PERMfr)</u>

The CRC E65 study was only designed to investigate the emission effects of permeation through hoses and fuel tanks. 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 grams per hour, 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 grams per hour (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.

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

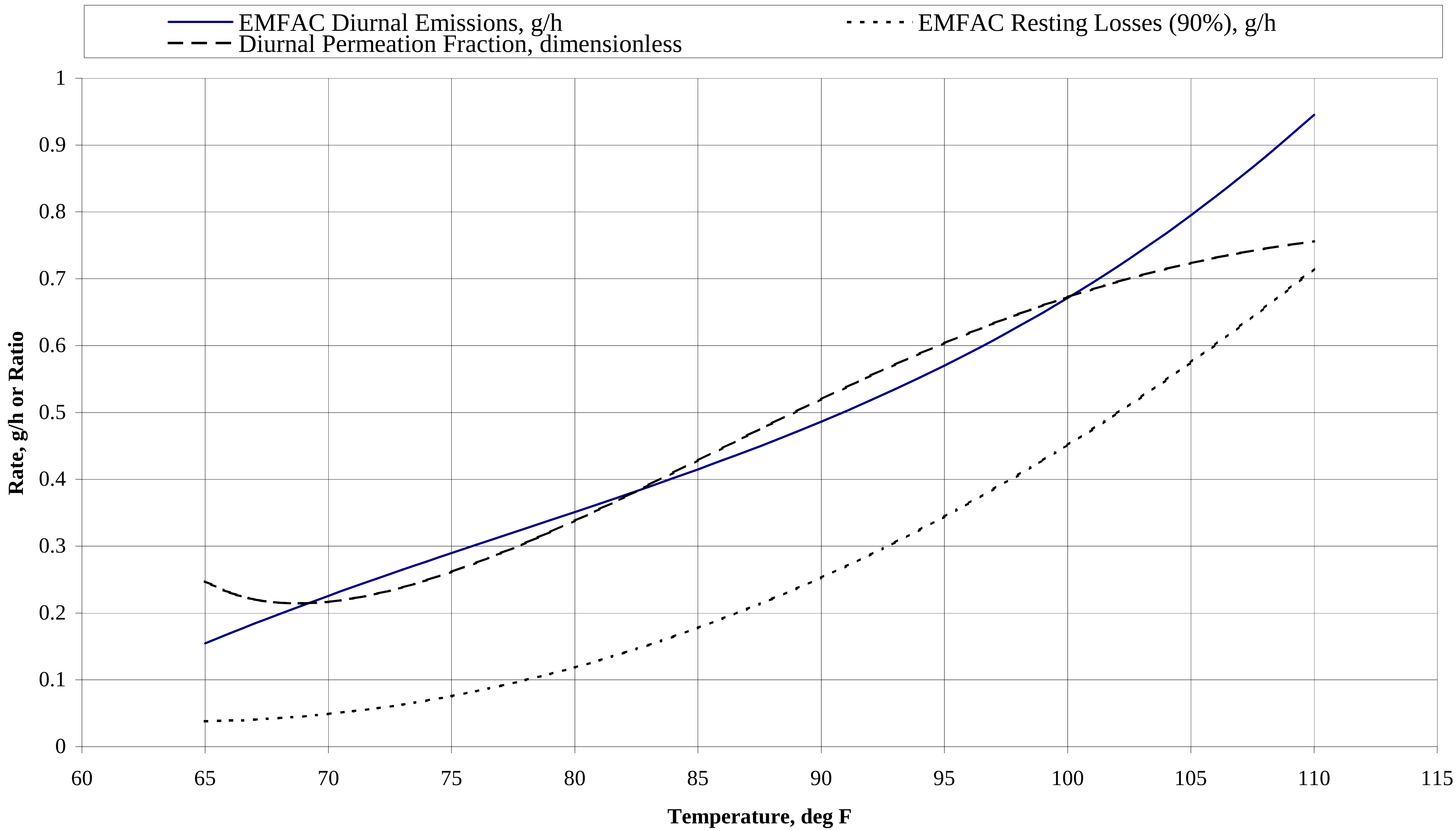


Table 6—Evap Tech group assignments

	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, available at www.arb.ca.gov/msei/onroad/doctable_test.htm

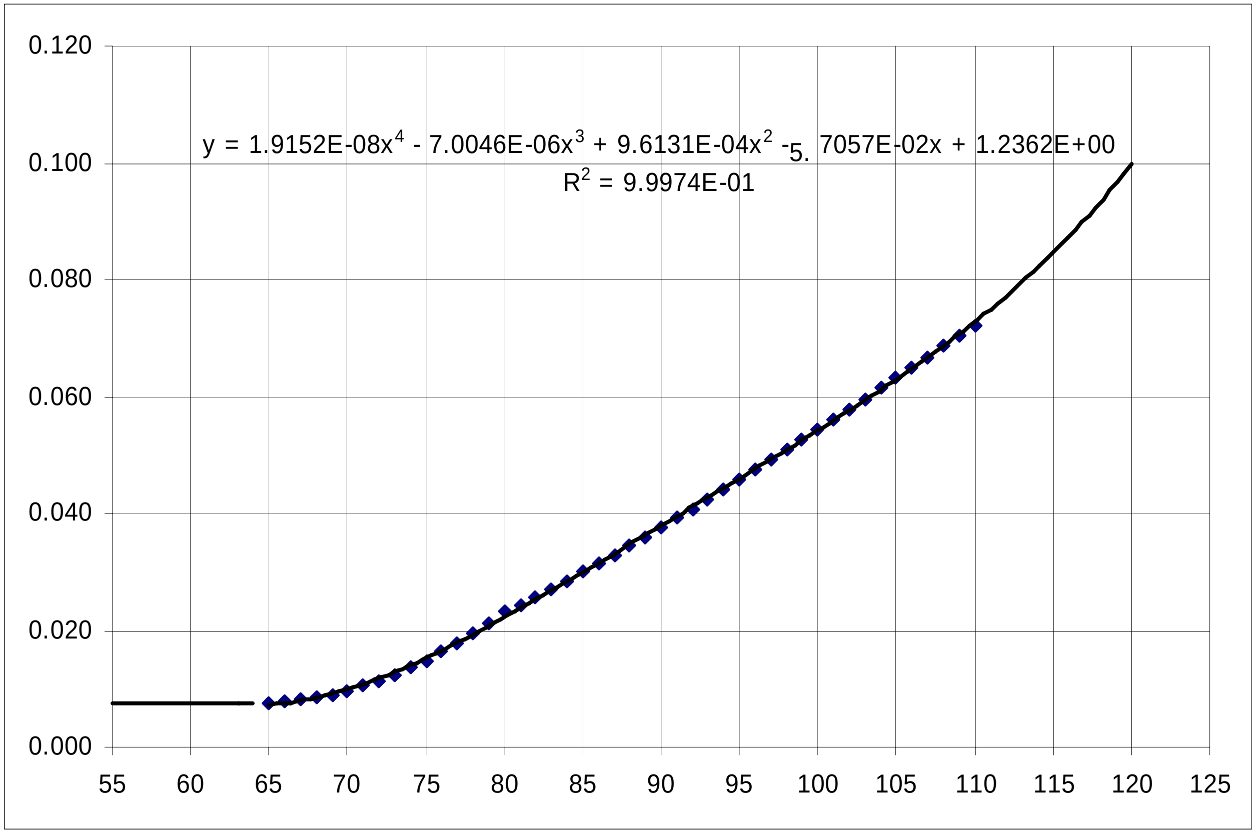
1) Note for Diurnal/Resting and Hot Soak emissions, the truck rates have been cloned from cars.
2) For Hot Soak emissions, the Pre-Enhanced Evap FI group has 3 tech groups (pre-79, 79-85, and 86+). I suggest using rates from the 86+ grouping since its rates are based on a larger data set.
3) For running losses, the zero-evap group cloned from the enhanced 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 leakers. 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.

Figure 5
Running Loss Permeation Fraction Example
Car Enhanced Evap Normal



Note: Constant 0.008 value below 65°F.

Table 7—Hot Soak Permeation Fraction Correlations

Tech Groups	Fuel sys/ Model yr	Regime	Coefficients for Hot Soak Permeation Factor Correlations					Domain Restrictions			
			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 8a—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 8b—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 EMFAC model 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).

In updating the EMFAC model, the individual changes to the model are compared incrementally. EMFAC 2007 Working Draft version 2.22.3 is the version including the fuel correction factors, I&M updates, Bug fixes, Brakewear PM, Accrual Rates, I&M Dialog Changes, Additional FCF and BER Changes, VMT-Matching by Fuel type, Addition of Other Bus Category, New Populations for 2000 to 2003 calendar years, Redistribution of Heavy-duty diesel vehicle populations, and Regime-specific Evaporative Calculations. Version 2.22.4 has all those changes plus the ethanol permeation routine described above.

For these comparisons the model was run with EMFAC 2002 Default Summer Planning Temperature profiles.

Table 14 shows a detailed 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 increase in ROG emissions is about 3% of the total on-road vehicle ROG emissions in 2005, falling to 2.3% in 2020. The total ROG emissions and the increase due to ethanol fall with time. The ethanol effect falls more quickly with time because of advances in evaporative control in the newer cars.

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

Air Basin	ver 2.22.3 ROG_Tot	ver 2.22.4 ROG_Tot	Difference	% Difference
	tpd	tpd	tpd	
Statewide	1128.1	1128.1	0.0	0.0
South Coast Air Basin	447.6	447.6	0.0	0.0
San Joaquin Valley AB	121.6	121.6	0.0	0.0
Sacramento Valley AB	99.2	99.2	0.0	0.0
San Diego Air Basin	86.6	86.6	0.0	0.0
San Francisco Bay Area	218.0	218.0	0.0	0.0

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

Air Basin	ver 2.22.3 ROG_Tot	ver 2.22.4 ROG_Tot	Difference	% Difference
	tpd	tpd	tpd	
Statewide	961.6	989.9	28.4	3.0
South Coast Air Basin	370.4	382.0	11.6	3.1
San Joaquin Valley AB	109.1	113.1	4.1	3.7
Sacramento Valley AB	88.5	92.0	3.5	3.9
San Diego Air Basin	75.4	77.5	3.5	2.9
San Francisco Bay Area	176.4	180.9	4.4	2.5

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

Air Basin	ver 2.22.3 ROG_Tot	ver 2.22.4 ROG_Tot	Difference	% Difference
	tpd	tpd	tpd	
Statewide	725.3	745.3	20.1	2.8
South Coast Air Basin	267.3	275.1	7.8	2.9
San Joaquin Valley AB	83.5	86.5	3.0	3.6
Sacramento Valley AB	68.9	71.5	2.6	3.7
San Diego Air Basin	56.5	58.0	2.6	2.7
San Francisco Bay Area	136.0	139.2	3.2	2.3

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

Air Basin	ver 2.22.3 ROG_Tot	ver 2.22.4 ROG_Tot	Difference	% Difference
	tpd	tpd	tpd	
Statewide	549.2	563.2	14.0	2.6
South Coast Air Basin	204.1	209.4	5.3	2.6
San Joaquin Valley AB	62.6	64.7	2.1	3.3
Sacramento Valley AB	51.5	53.2	1.8	3.4
San Diego Air Basin	43.9	45.0	1.8	2.4
San Francisco Bay Area	99.4	101.6	2.2	2.2

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

Air Basin	ver 2.22.3 ROG_Tot	ver 2.22.4 ROG_Tot	Difference	% Difference
	tpd	tpd	tpd	
Statewide	432.0	442.1	10.1	2.3
South Coast Air Basin	161.8	0.0	3.8	2.4
San Joaquin Valley AB	49.1	50.6	1.5	3.0
Sacramento Valley AB	39.8	41.1	1.2	3.1
San Diego Air Basin	36.2	37.0	1.2	2.2+
San Francisco Bay Area	75.2	76.7	1.5	2.0

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