EMFAC Modeling Change Technical Memo

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

LEAD: BEN HANCOCK

SUMMARY

Following publication of the tech memo entitled “Increased Evaporative Emissions from On-road Motor Vehicles due to Ethanol Permeation”, ARB staff have made revisions to the ethanol permeation estimates based on discussions with stakeholders. The three revisions are described below.

First, Staff reduced the augmentation ratio for liquid leakers from 1.05 to 1.02. Staff had originally assumed a small, non-unity value because of lack of data from the E65 project. Industry Stakeholders pointed out that the value 1.02 resulted in absolute daily emission rates more like normal emitters.

Second, additional ethanol permeation data was received from CRC project E65-3. A near-zero evap car was tested. A zero-evap car was tested. The hour-by-hour augmentation ratio data were added to the bulk of the data for the normal emitters from E65. This changed the normal augmentation ratio from 2.55 to 2.4.

Third, in correlating hot soak permeation fractions, the resting loss correlation previously assumed for moderate trucks was incorrect. The proper resting loss correlation was substituted and a new permeation fraction fit was produced for this regime.

The emissions estimates for these three changes are shown below. As shown in Table 1, the impacts for 2002 are zero because ethanol oxygenate was phased in between 2003 and 2004. In 2015 the Statewide emissions effect due to this program change was 2.8 tpd decrease. This is mostly due to the lower expected diurnal permeation emissions from normal vehicles because of the augmentation ratio decrease.

Table 1
Summary of Emissions Changes due to Program Modification
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 Program Modification
Calendar Year 2015

Air Basin	Emission Changes by Pollutant, tons per day				
	ROG	CO	NOx	CO_2	PM
Statewide	-2.8	0.0	0.0	0.0	0.0
South Coast	-0.9	0.0	0.0	0.0	0.0
San Joaquin Valley	-0.4	0.0	0.0	0.0	0.0
Sacramento Valley	-0.3	0.0	0.0	0.0	0.0
San Diego	-0.2	0.0	0.0	0.0	0.0
San Francisco Bay Area	-0.5	0.0	0.0	0.0	0.0

AFFECTED SOURCE CODE

Affected source code is shown in Appendix A

The affected source code is in EvapEthanol.f90 (10/28/05), containing the Module EvapEthanol. Subroutine InitEthanol.

METHODOLOGY FOR REVISION

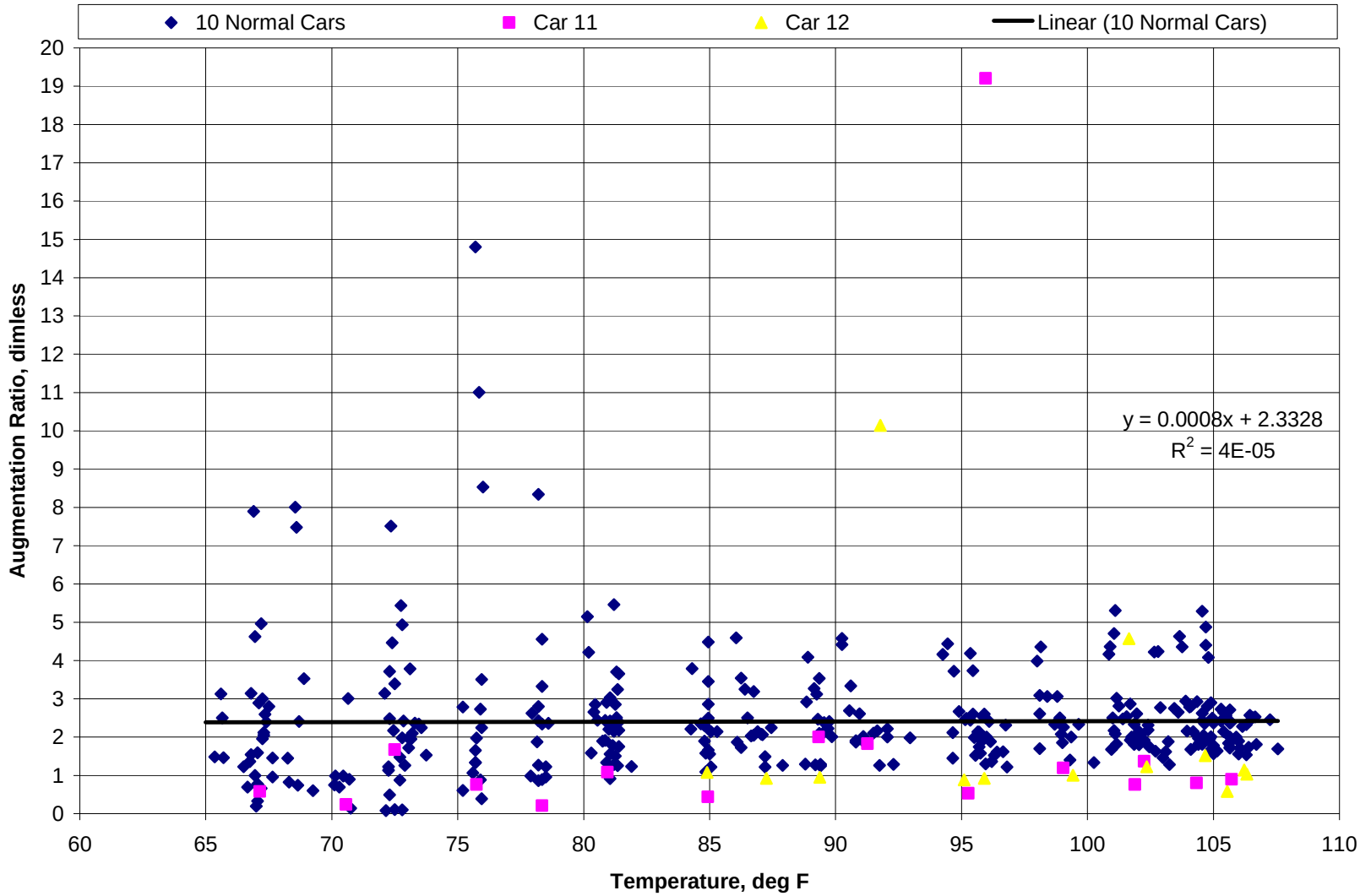
Separate ethanol-MTBE ratios were derived from data for normal and moderate emitters. Staff originally assumed a small, non-unity ratio (1.05) for liquid leakers, since there was E65 data that could be applied to normal emitters and moderate emitters, but none for high emitters (liquid leakers). Industry Stakeholders pointed out that the value 1.02 resulted in absolute daily emission rates more like normal emitters. It was agreed to change this value to 1.02. That is shown in bold in Table 3 below.

Table 3—Augmentation ratio values

Emitter Category	Ratio
Normals	**2.4**
Moderates	1.20
Liquid Leakers	**1.02**

After the original analysis was performed, two newer-technology cars were tested. The hour-by-hour ratio values for the 8 normal cars from E65 and the two newer cars from E65-3 are shown in Figure 1. The 48-hourly ratio points for each of the 8 normal cars appear as diamonds. The 24-hourly ratio points for the 2004 near-zero evap car appear as squares. The 24-hourly ratio points for the 2004 zero-evap car appear as triangles. Zero values and negative values were excluded. The values for the two newer cars generally are located around 1.0 for all the temperatures. The new regression line for the whole data ensemble is shown in the figure. The resulting average ratio is shown in Table 3 above. The addition of the two new cars lowered the value to 2.4 from 2.55.

Figure 1
Augmentation Ratio Normals with E65-3



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.

In the original work, the wrong resting loss correlation was chosen for the Truck running loss moderate pre-enhanced evap. The correct values were inserted, and the ratio re-fitted. The new results are shown in bold in Table 4.

Table 4—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		**4.3946E-07**	**-3.4311E-05**	**-1.0802E-03**	**9.7983E-02**	**T < 65**	**PF = 0.003**
			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

Estimates of the effect of these three changes to the ethanol permeation estimates in the EMFAC model are provided in Tables 5 through 9 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.

As a result of these revisions ROG emissions are reduced by approximately 0.5% for all calendar years and regions of the State. This percentage change is equivalent to a Statewide reduction in ROG emissions of approximately 4 tpd in calendar year 2005.

In updating the EMFAC model, the individual changes to the model are compared incrementally. EMFAC 2007 Working Draft version 2.242 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, Regime-specific Evaporative Calculations, Ethanol Permeation, Updated HHDD exhaust rates, new summer Temperature Profiles and Relative Humidities, New Populations for 2004, and updated VMTs and speed distributions. Version 2.243 has all those changes plus the modified ethanol permeation routine described above.

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 change in the augmentation for normal vehicles in the diurnal and resting loss process.

Table 5
Summary of Emissions Changes due to Program Modifications
Calendar Year 2002

Air Basin	ver 2.242 ROG_Tot	ver 2.243 ROG_Tot	Difference	% Difference
	tpd	tpd	tpd	
Statewide	1184	1184	0.0	0.0%
South Coast Air Basin	454	454	0.0	0.0%
San Joaquin Valley AB	132	132	0.0	0.0%
Sacramento Valley AB	104	104	0.0	0.0%
San Diego Air Basin	88	88	0.0	0.0%
San Francisco Bay Area	233	233	0.0	0.0%

Table 6
Summary of Emissions Changes due to Program Modifications
Calendar Year 2005

Air Basin	ver 2.242 ROG_Tot	ver 2.243 ROG_Tot	Difference	% Difference
	tpd	tpd	tpd	
Statewide	1019	1015	-4.2	-0.4%
South Coast Air Basin	385	384	-1.4	-0.4%
San Joaquin Valley AB	122	121	-0.6	-0.5%
Sacramento Valley AB	93	92	-0.5	-0.5%
San Diego Air Basin	72	72	-0.3	-0.4%
San Francisco Bay Area	186	186	-0.8	-0.4%

Table 7
Summary of Emissions Changes due to Program Modifications
Calendar Year 2010

Air Basin	ver 2.242 ROG_Tot	ver 2.243 ROG_Tot	Difference	% Difference
	tpd	tpd	tpd	
Statewide	743	740	-3.3	-0.4%
South Coast Air Basin	256	255	-1.0	-0.4%
San Joaquin Valley AB	98	97	-0.5	-0.5%
Sacramento Valley AB	72	72	-0.4	-0.6%
San Diego Air Basin	54	53	-0.2	-0.4%
San Francisco Bay Area	139	138	-0.7	-0.5%

Table 8
Summary of Emissions Changes due to Program Modifications
Calendar Year 2015

Air Basin	ver 2.242 ROG_Tot	ver 2.243 ROG_Tot	Difference	% Difference
	tpd	tpd	tpd	
Statewide	564	561	-2.8	-0.5%
South Coast Air Basin	193	192	-0.9	-0.5%
San Joaquin Valley AB	74	73	-0.4	-0.6%
Sacramento Valley AB	55	55	-0.3	-0.6%
San Diego Air Basin	42	42	-0.2	-0.4%
San Francisco Bay Area	103	102	-0.5	-0.5%

Table 9
Summary of Emissions Changes due to Program Modifications
Calendar Year 2020

Air Basin	ver 2.242 ROG_Tot	ver 2.243 ROG_Tot	Difference	% Difference
	tpd	tpd	tpd	
Statewide	446	444	-2.4	-0.5%
South Coast Air Basin	152	151	-0.8	-0.5%
San Joaquin Valley AB	58	57	-0.4	-0.6%
Sacramento Valley AB	43	43	-0.3	-0.6%
San Diego Air Basin	35	35	-0.2	-0.5%
San Francisco Bay Area	79	78	-0.5	-0.6%