Draft

EMFAC Modeling Change Technical Memo

SUBJECT: CORRECTION FACTOR FOR INCREASED EVAPORATIVE EMISSIONS DUE TO ETHANOL REPLACEMENT IN OXYGENATED GASOLINE

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SUMMARY

Originally the emission benefits for Phase 2 RFG were correlated only to oxygen content and Reid vapor pressure without regard to the oxygenating species. Gasoline oxygenated with ethanol (EtOH) is seen in testing to have higher evaporative emissions than equivalent vapor-pressure, equivalent oxygen-content methyl tertiary-butyl ether-(MTBE) containing fuel.

The Coordinating Research Council (CRC) sponsored a study in which the fuel systems of several vehicles were tested for diurnal evaporative permeation emissions with fuels containing MTBE and EtOH. The results were applied to the existing fleet in South Coast Air Basin and Sacramento.

Our analysis showed an 17-ton-per-day (ton/d) increase in the South Coast Air Basin on an ozone episodic day, an increase of 14% for evaporative emissions. For the Sacramento Metropolitan area, the increase in evaporative emissions due to ethanol was estimated to be 18% and 2.4 ton/d.

NEED FOR REVISION

MTBE was phased out of gasoline sold in California in 2003. This was in response to Governor Davis' Executive Order. Ethanol was required beginning in 2004. Therefore the fuel correction factors in EMFAC must be updated to estimate the impact that EtOH might have on emissions, most notably higher permeation through tank wall surfaces or line-fittings.

The object of this study was to quantify the impact, using the results of a recently completed study of diurnal permeation emissions on ethanol-containing fuels.

AFFECTED SOURCE CODE/VERSION

FCF_DATA.for (8/17/2001).

METHODOLOGY FOR REVISION

The Coordinating Research Council (CRC) sponsored a study (E65) in which the fuel systems of several cars were tested for diurnal evaporative emissions on fuels containing either MTBE or EtOH. The results of these tests were applied to the existing fleet in South Coast Air Basin and Sacramento Metropolitan Area. Although the test procedure was designed to estimate the impact of EtOH for the diurnal heating process, a methodology was also developed to adjust the emission inventory for the running loss and hot soak evaporative processes.

Ethanol-to-MTBE ratio. The CRC E65 permeation study results were correlated as the ratio of diurnal emissions on ethanol-containing fuel to emissions on MTBE-containing fuel as a function of temperature. For each of the 10 cars tested in the study, the 48 hourly diurnal emission rates were fitted to the best line (napierian or semi-log) for both ethanol-containing fuel and MTBE-containing fuel. The ratios of ethanol-fuel permeation emissions to MTBE-fuel permeation emissions were calculated from these correlations for each car, also a log function. No clear pattern for technology group or age could be discerned from these curves, so the ten ratio functions were arithmetically averaged to represent the impact on the entire vehicle population. This relationship is shown on Figure 1.

Diurnal/Resting Permeation fraction. The CRC E65 study was designed to investigate only 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 SHED enclosure. Thus the ethanol augmentation factor described above should only be applied to the part of the diurnal emissions attributable to permeation. To determine this fraction it was hypothesized that resting losses (emissions during the diurnal cycle where the temperature is falling or stable) were considered a reasonable approximation for permeation. Thus the ratio of resting loss to the diurnal loss (during the forced heating part of the cycle) would be approximately the fraction of permeation for the diurnal heating process. The ratio was corrected by a factor of 90% in recognition that not all resting loss would be permeation. The EMFAC correlations of resting loss and diurnal loss as a function of temperature were used to determine this ratio. The ratio relationship is shown in Figure 2.

Running loss temperature. Running losses were estimated as diurnal emissions taking place at elevated temperature. It was expected that the permeation losses for ethanol-containing fuel would be a strong function of temperature. We further hypothesized that most of the wall surface available for permeation was at the fuel tank. Therefore, it was necessary to estimate the fuel tank liquid temperature as a function of running time. Staff had previously instrumented a vehicle with thermocouples at several points of the fuel system. From this system we have temperature-time histories during a running loss cycle and the subsequent hot soak. There were two start temperatures, 75°F and 88°F. A routine was programmed to use a profile parallel to the 75-degree curve below 75°F standard or ambient temperature, to use a profile parallel to the 88-degree curve above 88°F, and to interpolate between the two curves between the temperatures of 75 and 88°F starting temperatures. The relationship is shown in Figure 3.

Permeation fraction for running loss. Staff desired to apply the ethanol augmentation results of the E65 study evaluated at the warm running loss temperatures only to the permeation fraction of running loss. We hypothesized that resting loss was the surrogate for permeation, so, the ratio of resting loss in grams per hour to running loss in those units would be a measure of the permeation fraction for running loss, analogous to the diurnal process. EMFAC uses a correlation for cumulative running loss emissions as a function of start temperature and time of operation. This was cross-correlated with the temperature-time profiles developed above and divided into the resting loss calculated at those temperatures to derive the permeation fraction. This relationship is shown in Figure 4.

Permeation fraction for hot soak. To be able to generalize the E65 permeation results to processes other than diurnal heating, staff developed a permeation fraction for hot soak and a hot-soak temperature for evaluation of the ethanol augmentation ratio. The hot soak temperatures were assumed to be the weighted running loss tank temperatures calculated in the running loss section above, representing fuel temperature at the end of a trip. The permeation fraction for hot soak was calculated as the ratio of resting loss in grams per hour to hot soak emissions in those units. EMFAC has a hot-soak correlation of test results as a function of ambient temperature and fuel volatility (RVP). The ratio relationship is shown in Figure 5.

INVENTORY EFFECTS

For the evaporative processes for South Coast Air Basin, this treatment of the E65 study results indicate that the diurnal emissions would rise by 9 ton/d, the running loss emissions would rise by 4 ton/d and the hot soak emissions would rise by 4 ton/d, overall a 15% increase.

The fleet started with a permeation diurnal evaporative emission rate of 1.0 grams per day per unit, and with ethanol-oxygenated fuel the result was 1.9 g/d. The 10-car E65 study had results of 2.1 g/d on Phase 2-MTBE fuel and 3.6 g/d on E10 (Phase 2 fuel with ethanol). The E65 study heated the cars from 65°F to 105°F, a very harsh and high-emitting temperature profile. The ambient summer-day South Coast temperature profile is from 61°F to 83°F. It should also be noted that for most of the cars in the basin the evaporative standard (when they were new) was 2 g/d (on the 65-to-105°F profile).

The E65 study from which the permeation behavior was drawn only performed diurnal tests. Running loss emissions are much higher on an absolute basis than diurnal emissions. The estimated fraction of permeation for running losses under the South Coast Air Basin summer conditions is about 6%. The temperature profile-averaged ethanol augmentation generalized from the E65 study is about 1.93 (or almost double due to ethanol). So our estimate is about a 5% increase of running loss emissions.

For hot-soak emissions, the estimated fraction permeation was about 29%, the time- and emissions-averaged fraction of permeation. This higher permeation fraction contributed to the higher sensitivity of hot soak emissions to ethanol, about a 28% increase.

Under the more extreme summer profile for the Sacramento Metropolitan Area, the fleet permeation diurnal emissions went from 1.3 g/d/unit on Phase 2 gasoline with MTBE to 2.5 g/d/unit on gasoline oxygenated with ethanol. The hourly temperature range was 59 to 91°F.

Figure 1
Ethanol Augmentation ratio from E65 Diurnals

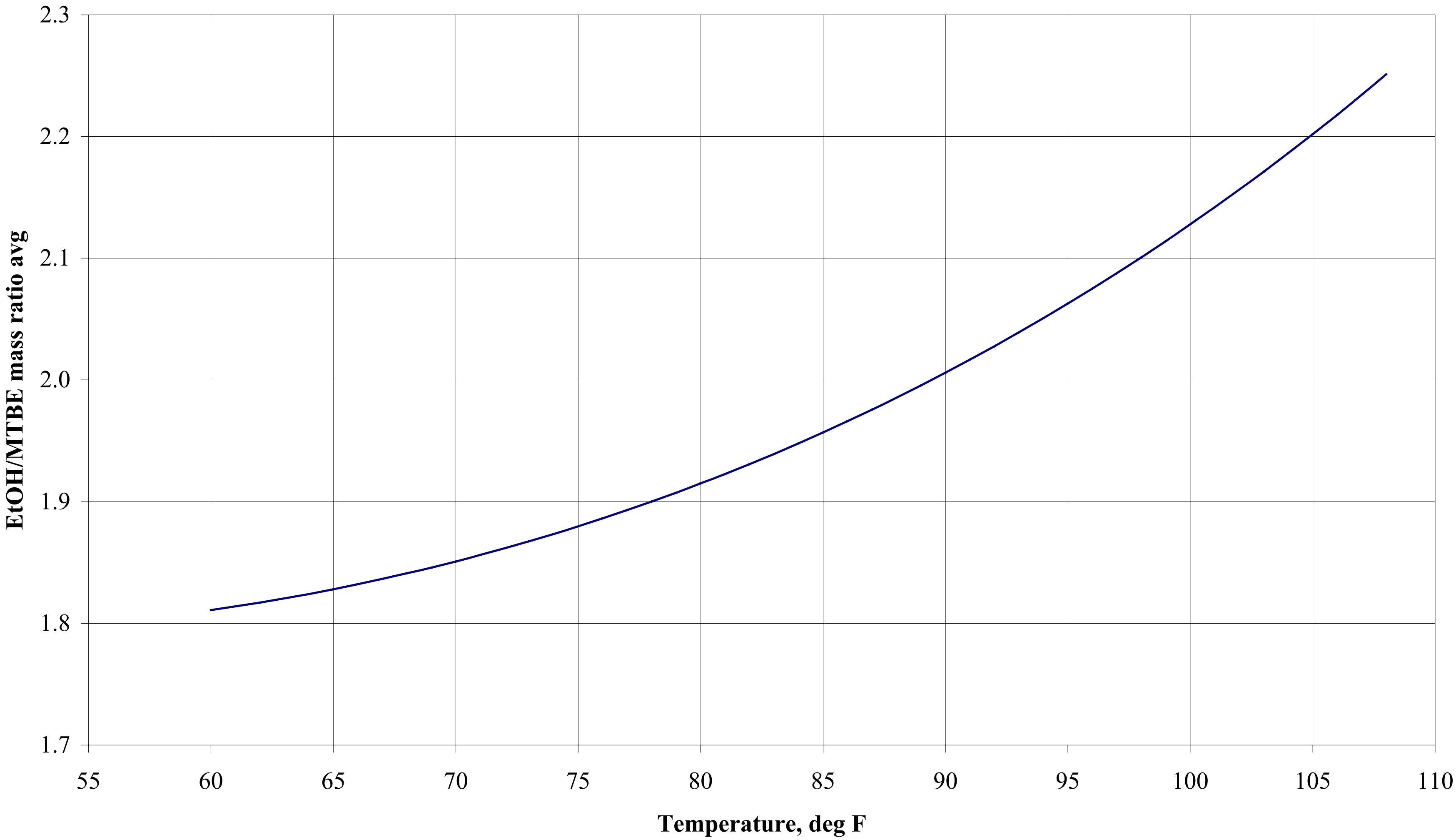


Figure 2
Diurnal Permeation Fraction

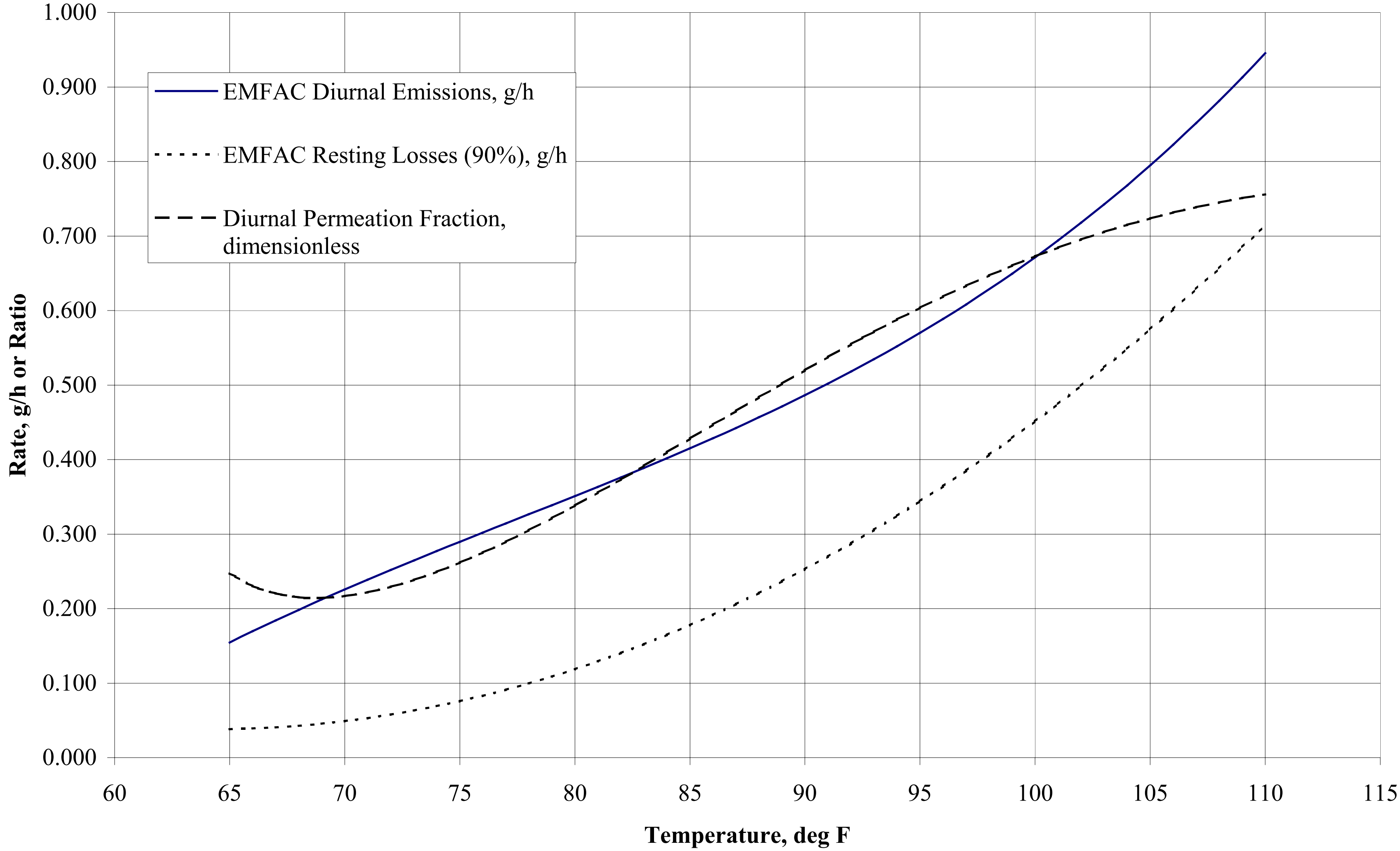


Figure 3
Running Loss Heating

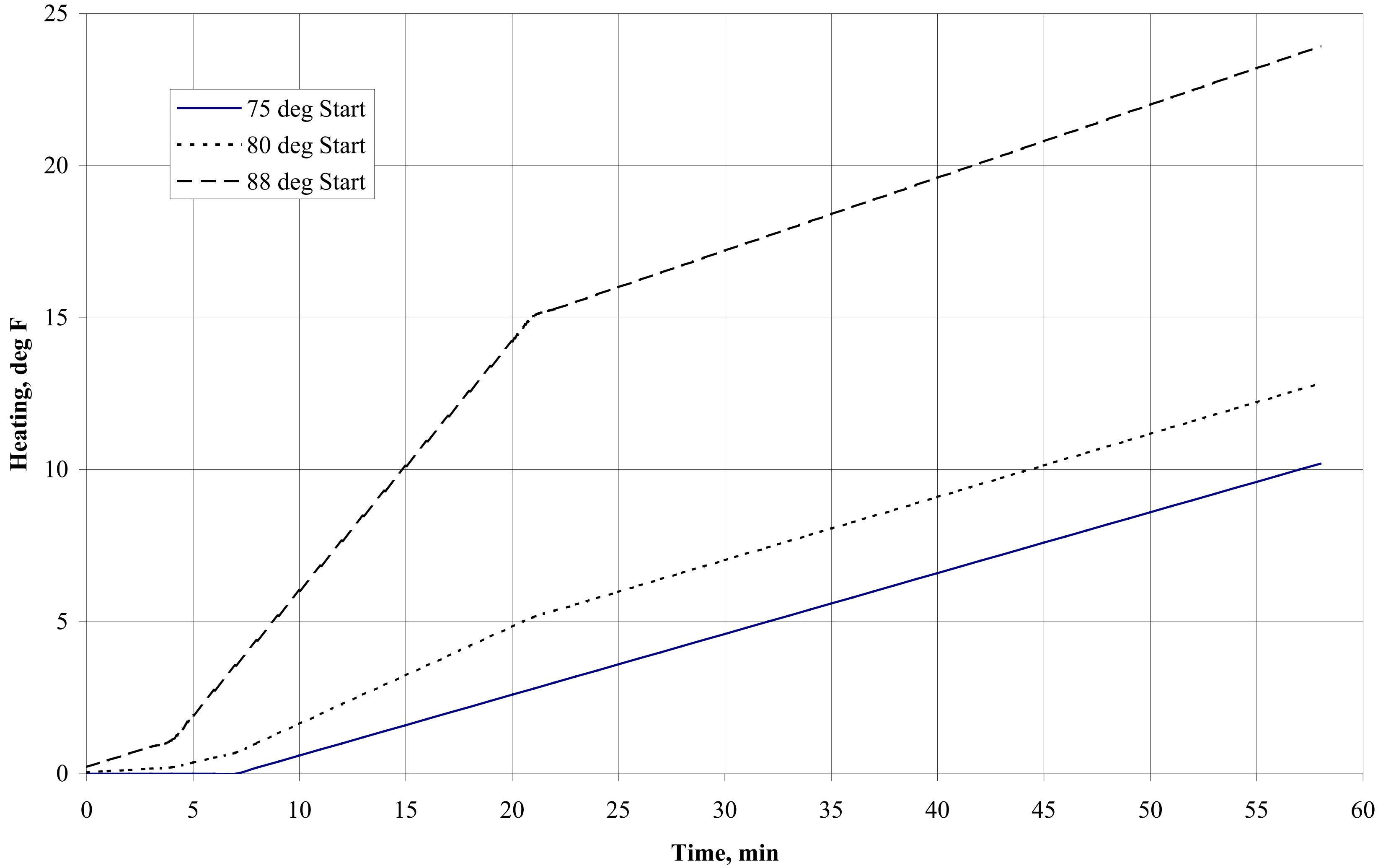


Figure 4
Running Loss Permeation Fraction

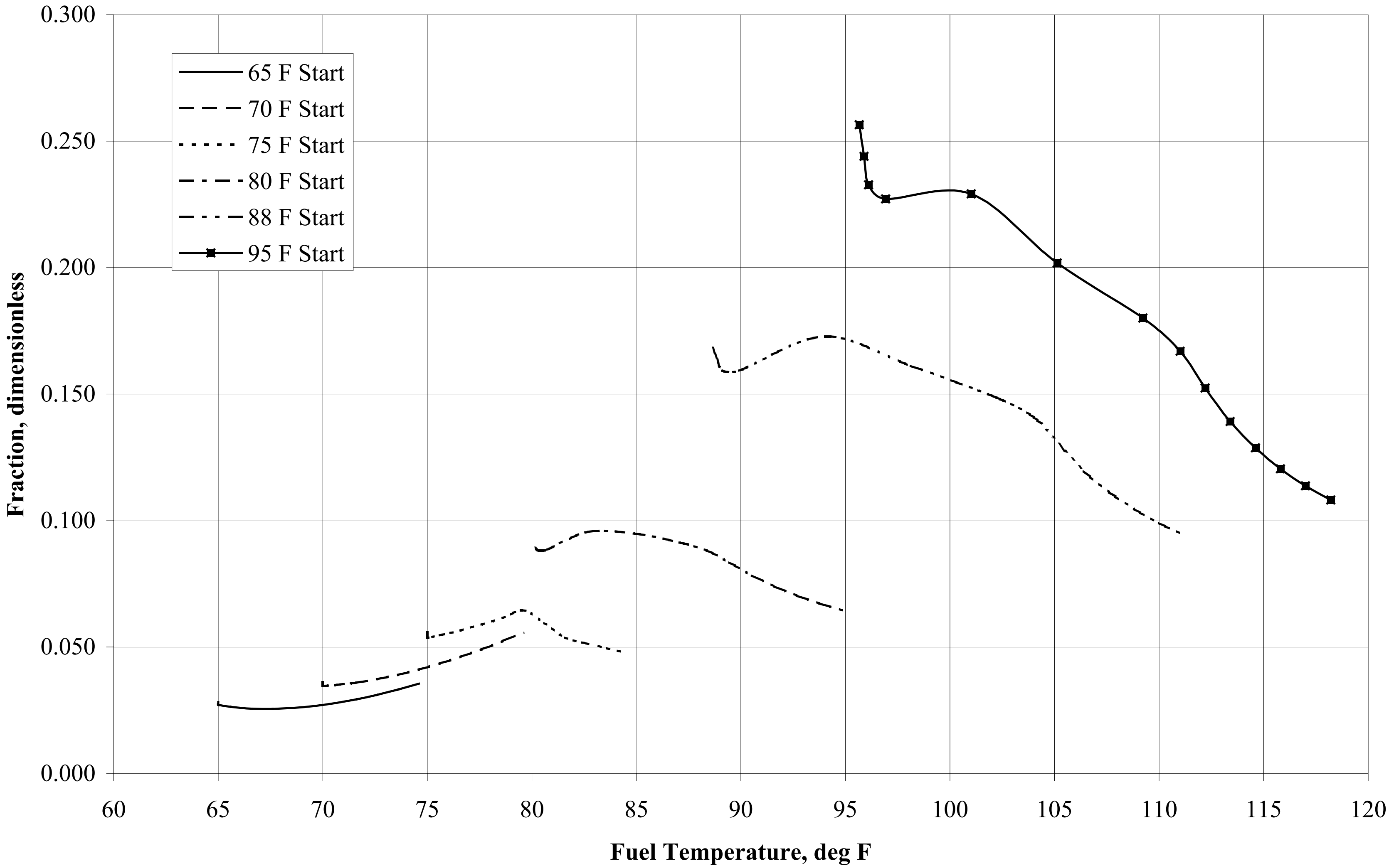
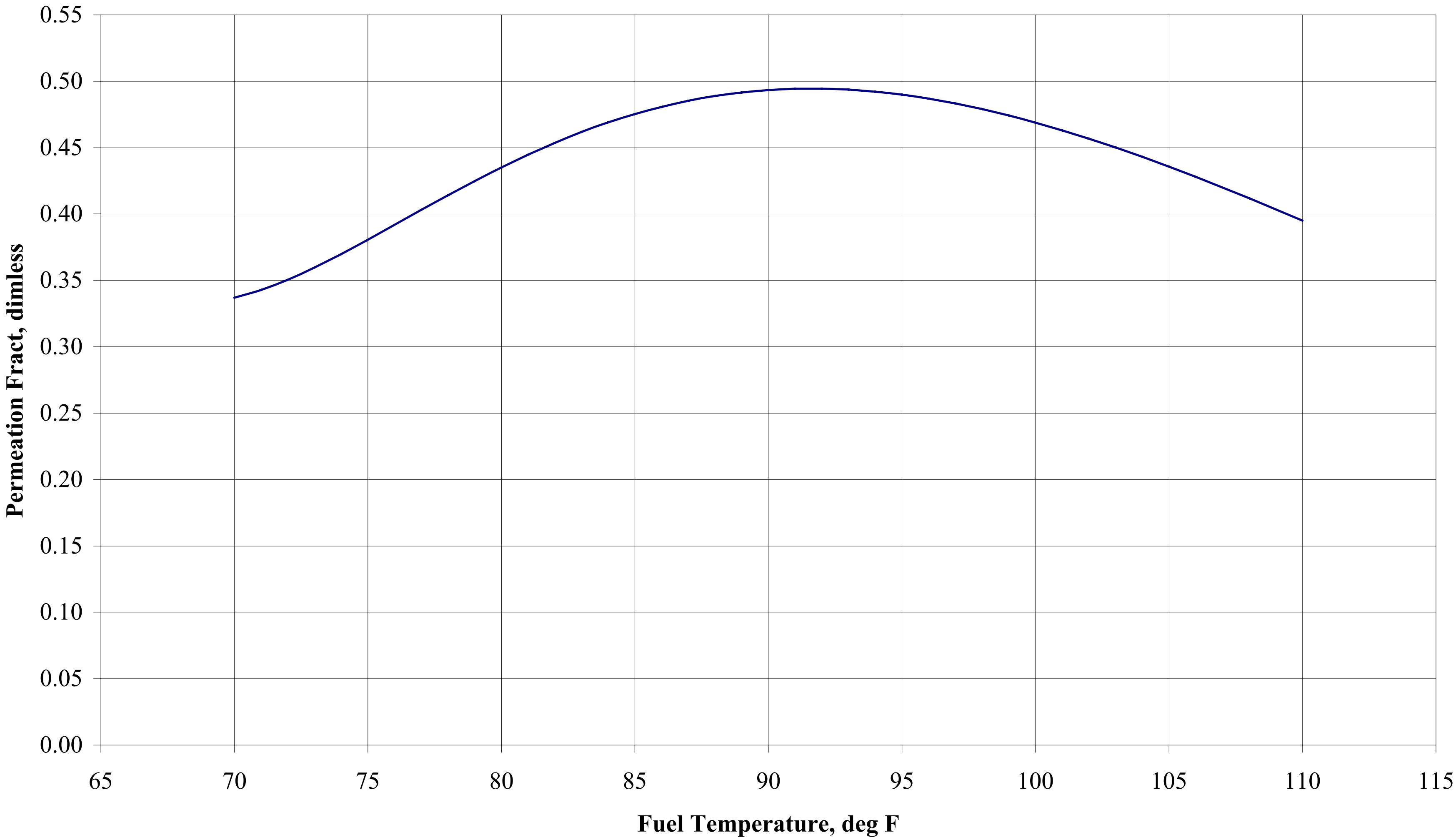


Figure 5
Permeation Fraction, Hot Soak



APPENDIX: SPREADSHEET CALCULATION DETAILS

Table 1 contains the details of the analysis for the South Coast Air Basin. Table 2 contains the details for the Sacramento Metropolitan Area. Table 1 is based on an hour-by-hour EMFAC 2002 (version 2.2: April 23, 2003) run for a summer episodic day in South Coast Air Basin for 2004. Columns A through J restate the EMFAC 2002 results for a summer day on commercial Phase 2 fuel. Column B is the average ambient temperature for each hour (summer ozone episodic).

Columns L through T concern themselves only with diurnal and resting losses. Column L is the hour-by-hour diurnal plus resting loss emissions for the basin, repeated from columns F and J. Column M is the ambient temperature repeated. Column N is the assumed fraction of the diurnal emissions that is permeation, a function of temperature. It is calculated from the ratio of 90% of resting loss to diurnal emissions. That is, the resting loss is assumed to be 90% permeation. Column O is the diurnal emission augmentation factor from the CRC Permeation Study. This was calculated from the ratio of the individual car hour-by-hour diurnal results on the two fuels. The ratios for the ten cars were arithmetically averaged. Column Q is the absolute permeation emissions for the hour. It is the product of the fraction of permeation in column N and the total diurnal emissions in column L and one minus the liquid leaker emissions fraction in cell L 8. Thus the emissions from liquid leakers is excluded from the effects of ethanol. Column R is the product of column O and column Q, the ethanol-adjusted permeation emissions. Column S is the difference between column R and column Q. It is the absolute increase in tons per hour due to ethanol. Column T is the total adjusted diurnal emissions, the sum of column S and column L.

Columns V through AD are the running loss calculations. Column V is the EMFAC 2002 hourly running loss results for the SCAB 2004 fleet using commercial Phase 2 fuel, copied from column I. Column W is the running loss temperature, the weighted average fuel temperature in the fuel tank for the operating cars. The ethanol augmentation or permeation results were correlated to this temperature for the running loss and hot-soak processes. It was calculated from measurements of liquid fuel temperature in the fuel tank as a function of time of operation and starting (ambient) temperature. These temperature-vs-time profiles were calculated from the ambient (starting) temperatures for each hour weighted by the frequency of trip duration from EMFAC. Column X is the fraction of permeation for running loss as a function of temperature. It is the ratio of 90% of resting loss at temperature to running loss (a function of time of operation correlated to liquid fuel temperature). The value for each hour is the weighted result based on the frequency distribution of operating time. Column Y is the ethanol-MTBE augmentation factor from the CRC E65 diurnal study evaluated at the running loss temperature for the hour. Column AA is the absolute tons per hour of permeation emissions from running loss. It is calculated as the product of the total running loss emissions in column V and the fraction of permeation in column X and one minus the liquid leaker emissions fraction in cell V 8. Column Z is the non permeation remainder of the total running loss, calculated as the difference between column V and column AA. Column AB is the corrected permeation running loss emissions, the product of column AA and the augmentation factor in column Y. Column AC is the absolute increase due to ethanol for running loss. It is the difference between column AB and column AA. Column AD is the total ethanol-adjusted running loss, the sum of column V and column AC.

The calculations for the ethanol effect on the hot soak process are contained in columns AF through AN. They parallel the calculations for running loss just discussed. The only differences are the beginning emission rates in column AF and the permeation fractions in column AH. Column AF contains the hour-by-hour hot soak emission rates for South Coast Air Basin. Column AG contains the running loss temperatures copied from column W. Column AH contains the fraction of permeation for the hot soak process. It is in general the ratio of 90% of resting loss at temperature to hot soak emissions for an hour at beginning temperature. For each hour the value shown is the time-frequency-weighted result. The rest of the calculation is analogous to the running loss process.

Table 1

Title : South Coast Air Basin Avg 2004 Summer Default Title
Version : Emfac2002 V2.2 Apr 23 2003
Run Date : 11/03/04 16:06:00
Scen Year: 2004 -- Model Years: 1965 to 2004
Season : Summer
Area : South Coast Air Basin Average
I/M Stat : I and M program in effect

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	
						Total Organic Gas Emissions					0.29 Liquid Leaker Fraction									
Time	Temperature	Vehicles	VMT/1000	Trips	Gasoline	Diurnal	Hot Soak	Running	Resting		Diurnal/resting	Temp	Fract Perm	EtOH/MTBE	Non Perm	Perm	Adj Perm	Delta Perm		
h	°F		kmi/h	#/h	kgal/h	ton/h	ton/h	ton/h	ton/h		ton/h	°F			ton/h	ton/h	ton/h	ton/h	ton/h	
0	64.0	9,266,894	3,300	503,001	162	0.	0.06	0.65	0.58		0.58	64.0	0.90	1.82	0.21	0.37	0.68	0.31	0.89	
1	63.3	9,266,894	1,074	250,954	55	0.	0.03	0.3	0.56		0.56	63.3	0.90	1.82	0.20	0.36	0.65	0.29	0.85	
2	62.8	9,266,894	1,089	126,096	61	0.	0.01	0.27	0.55		0.55	62.8	0.90	1.82	0.20	0.35	0.64	0.29	0.84	
3	62.3	9,266,894	493	103,524	26	0.	0.01	0.14	0.54		0.54	62.3	0.90	1.82	0.19	0.35	0.63	0.28	0.82	
4	61.9	9,266,894	1,393	171,472	71	0.	0.02	0.28	0.53		0.53	61.9	0.90	1.82	0.19	0.34	0.62	0.28	0.81	
5	61.6	9,266,894	2,649	264,605	138	0.	0.06	0.56	0.52		0.52	61.6	0.90	1.82	0.19	0.33	0.60	0.27	0.79	
6	62.5	9,266,894	11,626	1,083,300	588	1.33	0.19	2.03	0		1.33	62.5	0.34	1.82	1.01	0.32	0.58	0.26	1.59	
7	66.4	9,266,894	24,645	3,221,889	1,260	1.38	0.66	5.42	0		1.38	66.4	0.23	1.83	1.16	0.22	0.41	0.18	1.56	
8	70.9	9,266,894	22,627	3,324,432	1,197	1.68	0.77	5.36	0		1.68	70.9	0.22	1.86	1.42	0.26	0.49	0.23	1.91	
9	74.6	9,266,894	13,634	3,438,242	697	2.03	0.64	4.08	0		2.03	74.6	0.26	1.88	1.66	0.37	0.69	0.32	2.35	
10	77.9	9,266,894	14,558	3,496,570	753	2.23	0.77	4.14	0		2.23	77.9	0.30	1.90	1.75	0.48	0.91	0.43	2.66	
11	80.2	9,266,894	18,507	4,700,530	970	2.24	1.08	5.33	0		2.24	80.2	0.34	1.92	1.70	0.54	1.04	0.50	2.74	
12	81.9	9,266,894	19,320	5,062,047	1,019	2.34	1.3	5.77	0		2.34	81.9	0.37	1.93	1.72	0.62	1.19	0.57	2.91	
13	83.0	9,266,894	19,009	4,229,390	1,007	2.56	1.3	5.12	0		2.56	83.0	0.39	1.94	1.85	0.71	1.38	0.67	3.23	
14	83.3	9,266,894	22,254	4,513,089	1,179	2.52	1.36	5.9	0		2.52	83.3	0.40	1.94	1.81	0.71	1.38	0.67	3.19	
15	82.9	9,266,894	22,827	4,784,208	1,290	0.	1.38	6.13	1.05		1.05	82.9	0.90	1.94	0.38	0.67	1.30	0.63	1.68	
16	81.4	9,266,894	23,506	4,475,774	1,316	0.	1.34	6.1	0.96		0.96	81.4	0.90	1.93	0.35	0.61	1.18	0.57	1.53	
17	78.8	9,266,894	26,312	4,610,365	1,445	0.	1.27	6.42	0.81		0.81	78.8	0.90	1.91	0.29	0.52	0.99	0.47	1.28	
18	75.2	9,266,894	18,279	3,724,610	974	0.	0.79	4.52	0.7		0.7	75.2	0.90	1.88	0.25	0.45	0.84	0.39	1.09	
19	71.5	9,266,894	13,816	2,956,854	707	0.	0.56	3.39	0.62		0.62	71.5	0.90	1.86	0.22	0.40	0.74	0.34	0.96	
20	69.1	9,266,894	10,219	1,974,808	510	0.	0.37	2.31	0.62		0.62	69.1	0.90	1.85	0.22	0.40	0.73	0.34	0.96	
21	67.4	9,266,894	10,229	1,693,235	499	0.	0.27	2.07	0.61		0.61	67.4	0.90	1.84	0.22	0.39	0.72	0.33	0.94	
22	66.2	9,266,894	7,698	1,208,334	379	0.	0.19	1.53	0.61		0.61	66.2	0.90	1.83	0.22	0.39	0.71	0.32	0.93	
23	65.4	9,266,894	5,969	1,023,850	298	0.	0.14	1.27	0.61		0.61	65.4	0.90	1.83	0.22	0.39	0.71	0.32	0.93	
	1,715	9,266,894	315,033	60,941,179	16,601						**28.2**		0.37	1.88	17.6	10.5	19.8	**9.3**	**37.4**	ton/d
	71.4				654						2.76				1.73	1.03	1.94	0.91	3.67	g/d
											115				72	43	81	38	153	mg/h

Table 1 Continued

A	V	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP
	0.2 Liquid leaker Fraction										0.25 Liquid Leaker Fraction									
Time	Running Loss	RL Temp	Fract Perm	EtOH/ MTBE	non-perm	perm	corr	delta	Total		Hot Soak	HS Temp	Fract Perm	EtOH/ MTBE	non-perm	perm	adj perm	increase	Total	
h	ton/h	deg F			ton/h	ton/h	ton/h	ton/h	ton/h		ton/h	deg F			ton/h	ton/h	ton/h	ton/h	ton/h	
0	0.65	66	0.02	1.83	0.64	0.01	0.02	0.01	0.66		0.06	66	0.33	1.83	0.05	0.01	0.03	0.01	0.07	
1	0.3	65	0.03	1.83	0.29	0.01	0.01	0.01	0.31		0.03	65	0.34	1.83	0.02	0.01	0.01	0.01	0.04	
2	0.27	65	0.02	1.83	0.26	0.01	0.01	0.00	0.27		0.01	65	0.33	1.83	0.01	0.00	0.00	0.00	0.01	
3	0.14	64	0.03	1.82	0.14	0.00	0.01	0.00	0.14		0.01	64	0.35	1.82	0.01	0.00	0.00	0.00	0.01	
4	0.28	64	0.02	1.82	0.27	0.01	0.01	0.00	0.28		0.02	64	0.35	1.82	0.01	0.01	0.01	0.00	0.02	
5	0.56	65	0.02	1.83	0.55	0.01	0.02	0.01	0.57		0.06	65	0.34	1.83	0.04	0.02	0.03	0.01	0.07	
6	2.03	64	0.02	1.82	1.99	0.04	0.07	0.03	2.06		0.19	64	0.33	1.82	0.14	0.05	0.09	0.04	0.23	
7	5.42	68	0.03	1.84	5.30	0.12	0.23	0.10	5.52		0.66	68	0.30	1.84	0.51	0.15	0.28	0.13	0.79	
8	5.36	72	0.04	1.86	5.19	0.17	0.31	0.14	5.50		0.77	72	0.32	1.86	0.59	0.18	0.34	0.16	0.93	
9	4.08	76	0.05	1.88	3.91	0.17	0.31	0.15	4.23		0.64	76	0.35	1.88	0.47	0.17	0.32	0.15	0.79	
10	4.14	80	0.07	1.92	3.91	0.23	0.45	0.21	4.35		0.77	80	0.39	1.92	0.54	0.23	0.44	0.21	0.98	
11	5.33	83	0.09	1.94	4.96	0.37	0.72	0.35	5.68		1.08	83	0.41	1.94	0.74	0.34	0.65	0.32	1.40	
12	5.77	85	0.10	1.96	5.31	0.46	0.91	0.44	6.21		1.3	85	0.43	1.96	0.88	0.42	0.81	0.40	1.70	
13	5.12	87	0.11	1.98	4.67	0.45	0.88	0.44	5.56		1.3	87	0.43	1.98	0.88	0.42	0.83	0.41	1.71	
14	5.9	88	0.11	1.99	5.39	0.51	1.01	0.50	6.40		1.36	88	0.43	1.99	0.92	0.44	0.88	0.43	1.79	
15	6.13	88	0.11	1.98	5.60	0.53	1.05	0.52	6.65		1.38	88	0.43	1.98	0.93	0.45	0.89	0.44	1.82	
16	6.1	86	0.10	1.96	5.63	0.47	0.92	0.45	6.55		1.34	86	0.43	1.96	0.91	0.43	0.84	0.41	1.75	
17	6.42	82	0.08	1.93	6.02	0.40	0.77	0.37	6.79		1.27	82	0.41	1.93	0.88	0.39	0.75	0.36	1.63	
18	4.52	76	0.05	1.89	4.32	0.20	0.37	0.18	4.70		0.79	76	0.36	1.89	0.58	0.21	0.40	0.19	0.98	
19	3.39	73	0.04	1.86	3.28	0.11	0.20	0.09	3.48		0.56	73	0.32	1.86	0.42	0.14	0.25	0.12	0.68	
20	2.31	70	0.03	1.85	2.25	0.06	0.11	0.05	2.36		0.37	70	0.31	1.85	0.28	0.09	0.16	0.07	0.44	
21	2.07	68	0.03	1.84	2.02	0.05	0.09	0.04	2.11		0.27	68	0.30	1.84	0.21	0.06	0.11	0.05	0.32	
22	1.53	67	0.03	1.84	1.50	0.03	0.06	0.03	1.56		0.19	67	0.31	1.84	0.15	0.04	0.08	0.04	0.23	
23	1.27	66	0.02	1.83	1.25	0.02	0.04	0.02	1.29		0.14	66	0.31	1.83	0.11	0.03	0.06	0.03	0.17	
	79.09	1768	0.06	1.94	74.66	4.43	8.59	**4.16**	**83.25**	ton/d	**14.57**		0.29	1.93	10.30	4.27	8.26	**3.99**	**18.56**	ton/d
	0.23	73.7			0.22	0.01	0.02	0.01	0.24	g/mi	0.22				0.15	0.06	0.12	0.06	0.28	g/trip

Table 2

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	

Title : Sacramento AQMD Avg 2004 Summer Default Title
Version : Emfac2002 V2.2 Apr 23 2003
Run Date : 11/03/04 16:12:08
Scen Year: 2004 -- Model Years: 1965 to 2004
Season : Summer
Area : Sacramento Metropolitan AQMD Average
I/M Stat : I and M program in effect

						Total Organic Gas Emissions					0.29 Liquid Leaker Fraction									
Time	Temperature	Vehicles	VMT/ 1000	Trips	Gasoline	Diurnal	Hot Soak	Running	Resting		Diurnal/ resting	Temp	Fract Perm	EtOH /MTBE	Non Perm	Perm	Adj Perm	Delta Perm		
h	°F		kmi/h	#/h	kgal/h	ton/h	ton/h	ton/h	ton/h		ton/h	°F			ton/h	ton/h	ton/h	ton/h	ton/h	
0	63.9	862,141	287	47,309	13.4	0	0	0.05	0.06		0.06	63.9	0.90	1.82	0.02	0.04	0.07	0.03	0.09	
1	62.3	862,141	93	23,532	4.56	0	0	0.01	0.04		0.04	62.3	0.90	1.82	0.02	0.03	0.05	0.02	0.06	
2	61.4	862,141	97	13,026	5.48	0	0	0.02	0.04		0.04	61.4	0.90	1.82	0.02	0.03	0.05	0.02	0.06	
3	60.2	862,141	45	9,614	2.16	0	0	0.01	0.04		0.04	60.2	0.90	1.81	0.02	0.03	0.05	0.02	0.06	
4	59.2	862,141	123	15,927	5.94	0	0	0.01	0.03		0.03	59.2	0.90	1.81	0.01	0.02	0.03	0.02	0.05	
5	58.5	862,141	238	24,585	11.77	0	0	0.05	0.03		0.03	58.5	0.90	1.81	0.01	0.02	0.03	0.02	0.05	
6	59.3	862,141	1,015	100,235	48.71	0.08	0.01	0.19	0		0.08	59.3	0.79	1.81	0.04	0.04	0.08	0.04	0.12	
7	63.6	862,141	2,148	298,019	104.15	0.11	0.05	0.52	0		0.11	63.6	0.29	1.82	0.11	0.02	0.04	0.02	0.13	
8	69.0	862,141	1,998	310,542	100.77	0.15	0.06	0.54	0		0.15	69.0	0.21	1.85	0.16	0.02	0.04	0.02	0.17	
9	74.5	862,141	1,208	335,540	64.5	0.18	0.06	0.42	0		0.18	74.5	0.26	1.88	0.19	0.03	0.06	0.03	0.21	
10	78.9	862,141	1,280	335,772	68.71	0.22	0.06	0.44	0		0.22	78.9	0.32	1.91	0.21	0.05	0.10	0.05	0.27	
11	82.9	862,141	1,630	449,314	89.26	0.23	0.12	0.56	0		0.23	82.9	0.39	1.94	0.21	0.06	0.12	0.06	0.29	
12	85.6	862,141	1,690	476,164	92.47	0.25	0.14	0.6	0		0.25	85.6	0.44	1.96	0.21	0.08	0.15	0.08	0.33	
13	88.1	862,141	1,666	397,625	92.94	0.31	0.15	0.56	0		0.31	88.1	0.49	1.99	0.25	0.11	0.21	0.11	0.42	
14	90.1	862,141	1,950	424,496	108.21	0.32	0.18	0.64	0		0.32	90.1	0.52	2.01	0.25	0.12	0.24	0.12	0.44	
15	90.9	862,141	1,999	451,832	116.74	0.33	0.18	0.68	0		0.33	90.9	0.54	2.02	0.25	0.13	0.25	0.13	0.46	
16	90.3	862,141	2,063	419,952	121.86	0	0.19	0.67	0.16		0.16	90.3	0.90	2.01	0.06	0.10	0.21	0.10	0.26	
17	87.9	862,141	2,312	431,158	132.99	0	0.18	0.69	0.13		0.13	87.9	0.90	1.98	0.05	0.08	0.16	0.08	0.21	
18	83.3	862,141	1,599	348,353	84.24	0	0.11	0.48	0.11		0.11	83.3	0.90	1.94	0.04	0.07	0.14	0.07	0.18	
19	77.5	862,141	1,210	275,759	61.25	0	0.06	0.34	0.07		0.07	77.5	0.90	1.90	0.03	0.04	0.08	0.04	0.11	
20	72.4	862,141	891	183,551	42.89	0	0.04	0.21	0.06		0.06	72.4	0.90	1.86	0.02	0.04	0.07	0.03	0.09	
21	69.2	862,141	891	156,560	41.07	0	0.01	0.2	0.06		0.06	69.2	0.90	1.85	0.02	0.04	0.07	0.03	0.09	
22	66.7	862,141	671	112,155	31.18	0	0.01	0.15	0.06		0.06	66.7	0.90	1.84	0.02	0.04	0.07	0.03	0.09	
23	65.0	862,141	518	94,983	24.62	0	0.01	0.13	0.06		0.06	65.0	0.90	1.83	0.02	0.04	0.07	0.03	0.09	
	1,761	862,141	27,622	5,736,003	1,470						**3.1**		0.41	1.93	2.2	1.3	2.5	**1.2**	**4.3**	ton/d
	73.4				622						3.30				2.37	1.34	2.58	1.24	4.54	g/d
											137				99	56	108	52	189	mg/h

Table 2 Continued

A	V	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	
	0.2 Liquid leaker Fraction										0.25 Liquid Leaker Fraction									
Time	Running Loss	RL Temp	Fract Perm	EtOH/ MTBE	non-perm	perm	corr	delta	Total		Hot Soak	HS Temp	Fract Perm	EtOH/ MTBE	non-perm	perm	adj perm	increase	Total	
h	ton/h	deg F			ton/h	ton/h	ton/h	ton/h	ton/h		ton/h	deg F			ton/h	ton/h	ton/h	ton/h	ton/h	
0	0.05	66	0.02	1.83	0.05	0.00	0.00	0.00	0.05		0	66	0.33	1.82	0.00	0.00	0.00	0.00	0.00	
1	0.01	64	0.03	1.82	0.01	0.00	0.00	0.00	0.01		0	64	0.36	1.82	0.00	0.00	0.00	0.00	0.00	
2	0.02	64	0.02	1.82	0.02	0.00	0.00	0.00	0.02		0	64	0.36	1.82	0.00	0.00	0.00	0.00	0.00	
3	0.01	62	0.03	1.82	0.01	0.00	0.00	0.00	0.01		0	62	0.42	1.81	0.00	0.00	0.00	0.00	0.00	
4	0.01	61	0.03	1.82	0.01	0.00	0.00	0.00	0.01		0	61	0.45	1.81	0.00	0.00	0.00	0.00	0.00	
5	0.05	61	0.02	1.82	0.05	0.00	0.00	0.00	0.05		0	61	0.44	1.81	0.00	0.00	0.00	0.00	0.00	
6	0.19	61	0.02	1.81	0.19	0.00	0.01	0.00	0.19		0.01	61	0.43	1.81	0.01	0.00	0.01	0.00	0.01	
7	0.52	65	0.02	1.83	0.51	0.01	0.02	0.01	0.53		0.05	65	0.32	1.82	0.04	0.01	0.02	0.01	0.06	
8	0.54	70	0.03	1.85	0.53	0.01	0.03	0.01	0.55		0.06	70	0.31	1.85	0.05	0.01	0.03	0.01	0.07	
9	0.42	76	0.05	1.88	0.40	0.02	0.03	0.01	0.43		0.06	76	0.35	1.88	0.04	0.02	0.03	0.01	0.07	
10	0.44	82	0.08	1.93	0.41	0.03	0.05	0.03	0.47		0.06	82	0.41	1.91	0.04	0.02	0.04	0.02	0.08	
11	0.56	87	0.11	1.97	0.51	0.05	0.10	0.05	0.61		0.12	87	0.44	1.94	0.08	0.04	0.08	0.04	0.16	
12	0.6	91	0.13	2.01	0.54	0.06	0.13	0.06	0.66		0.14	91	0.45	1.96	0.09	0.05	0.09	0.05	0.19	
13	0.56	94	0.15	2.05	0.49	0.07	0.14	0.07	0.63		0.15	94	0.44	1.99	0.10	0.05	0.10	0.05	0.20	
14	0.64	97	0.17	2.09	0.55	0.09	0.18	0.09	0.73		0.18	97	0.44	2.01	0.12	0.06	0.12	0.06	0.24	
15	0.68	98	0.17	2.10	0.59	0.09	0.20	0.10	0.78		0.18	98	0.44	2.02	0.12	0.06	0.12	0.06	0.24	
16	0.67	98	0.17	2.10	0.58	0.09	0.19	0.10	0.77		0.19	98	0.44	2.01	0.13	0.06	0.13	0.06	0.25	
17	0.69	96	0.15	2.08	0.61	0.08	0.17	0.09	0.78		0.18	96	0.45	1.98	0.12	0.06	0.12	0.06	0.24	
18	0.48	88	0.11	1.98	0.44	0.04	0.08	0.04	0.52		0.11	88	0.44	1.94	0.07	0.04	0.07	0.03	0.14	
19	0.34	80	0.07	1.91	0.32	0.02	0.04	0.02	0.36		0.06	80	0.39	1.90	0.04	0.02	0.03	0.02	0.08	
20	0.21	73	0.04	1.87	0.20	0.01	0.01	0.01	0.22		0.04	73	0.33	1.86	0.03	0.01	0.02	0.01	0.05	
21	0.2	70	0.03	1.85	0.19	0.01	0.01	0.00	0.20		0.01	70	0.31	1.85	0.01	0.00	0.00	0.00	0.01	
22	0.15	68	0.03	1.84	0.15	0.00	0.01	0.00	0.15		0.01	68	0.30	1.84	0.01	0.00	0.00	0.00	0.01	
23	0.13	66	0.02	1.83	0.13	0.00	0.00	0.00	0.13		0.01	66	0.31	1.83	0.01	0.00	0.00	0.00	0.01	
	8.17	1836	0.08	2.03	7.49	0.68	1.38	**0.70**	**8.87**	ton/d	**1.62**		0.32	1.96	1.11	0.51	1.00	**0.49**	**2.11**	ton/d
	0.27	76.5			0.25	0.02	0.05	0.02	0.29	g/mi	0.26				0.18	0.08	0.16	0.08	0.33	g/trip