EMFAC Model Ethanol Permeation Modeling

California Air Resources Board
PTSD Mobile Source Analysis Branch
Analysis Section

Presentation Outline

- Overview of Method
- Diurnal
- Running Loss
- Hot Soak
- Off-Road Sources
- Results
- Future Changes

Overview of Method

- Took E65 (a study sponsored by Coordinating Research Council) diurnal values and generalized method to the California Fleet
- Augmentation ratio constant with temperature
- Lower augmentation by emission regime
- Augmentation applied to “permeation fraction” — temperature dependent
- Resting loss surrogate for permeation
- Process-specific permeation fractions
- Permeation fraction functions empirically fit for each tech group

Method Summary

$ER_{etoh} = ER_{mtbe} * (PERMfr * EtRFG2r + 1 - PERMfr)$

ER = emission rate

- Evaluated at ambient (diurnal) temperature
- EtRFG2r ratios from E65 data

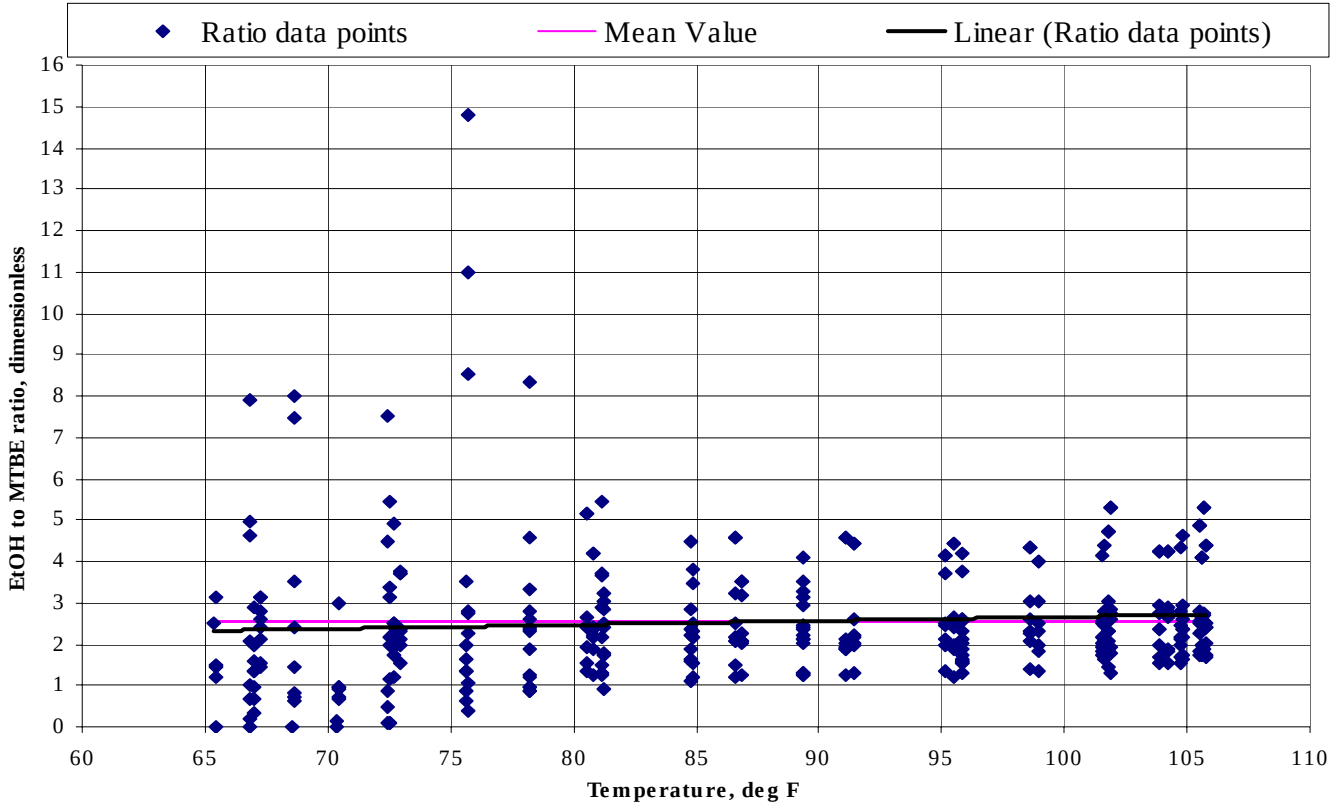
EtRFG2r = diurnal rate on EtOH fuel ÷ diurnal rate on MTBE fuel

- PERMfr fraction permeation. Resting loss is hypothesized to be surrogate for permeation.

$PERMfr = 0.9 * ER_{resting} * RVPTCF / (ER_{process} * RVPTCF)$

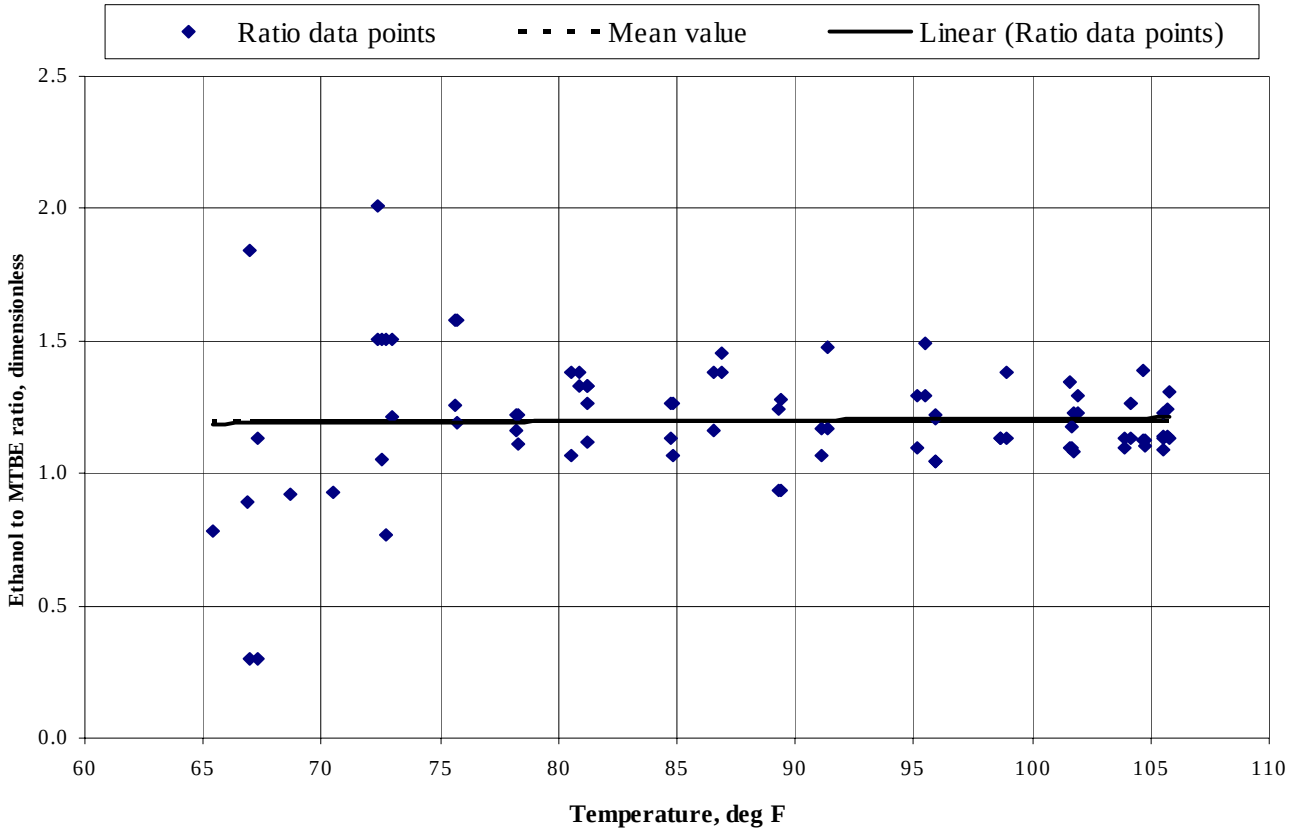
RVPTCF is the RVP/Temperature correction factor

E65 Diurnal Augmentation Ratios



Based on 8 vehicles, 48 hours each

E65 Diurnal Ratios, Moderates



Based on 2 vehicles, 72 hours total

Ethanol-to-MTBE ratio values

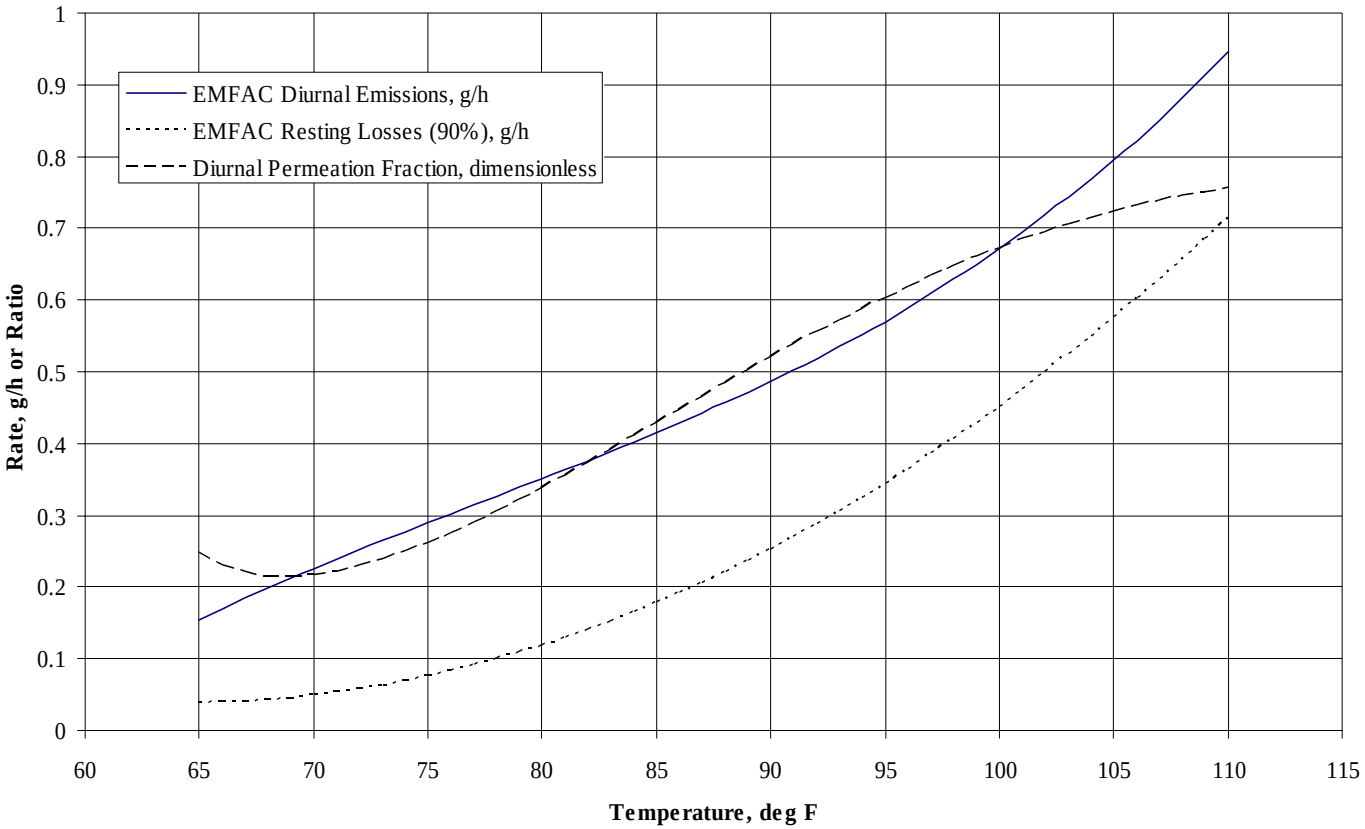
	Augmentation Ratio	Typical Values*	
		Diurnal permeation MTBE	Diurnal permeation EtOH
		g/d	g/d
Normals	2.55	0.98	2.49
Moderates	1.20	5.36	6.44
Liquid Leakers	1.05	49.0	51.5

* Estimated 2004 fleet SCOS temperature profile 70-98℉

Diurnal Permeation Fraction

- 48-hr runs
- Permeation only
- Resting loss surrogate of permeation (90% of resting loss is thought to be permeation)

Diurnal Permeation Fraction



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

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

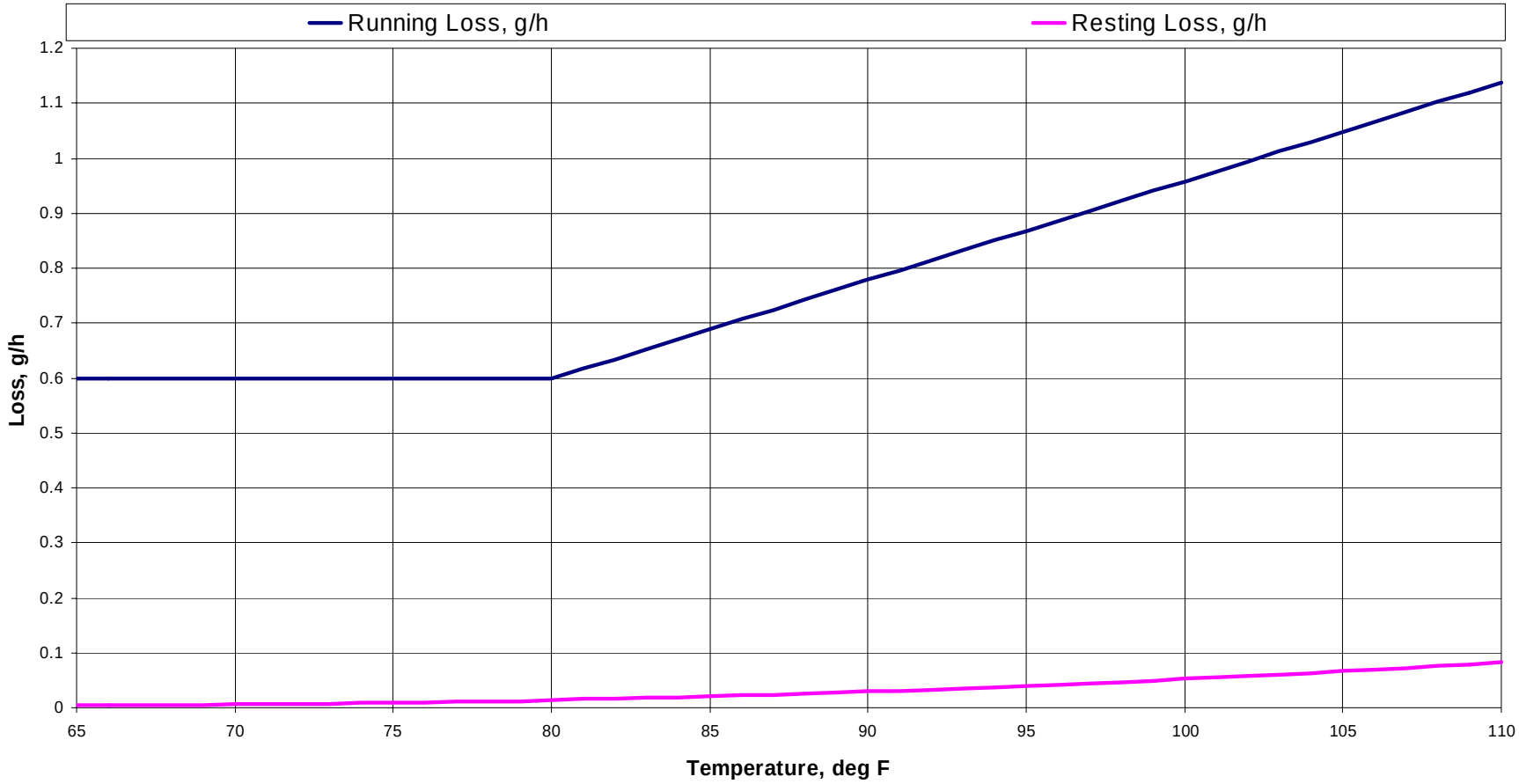
Note: TBI is throttle-body injection. PFI is port fuel injection. Carb is carbureted.

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.

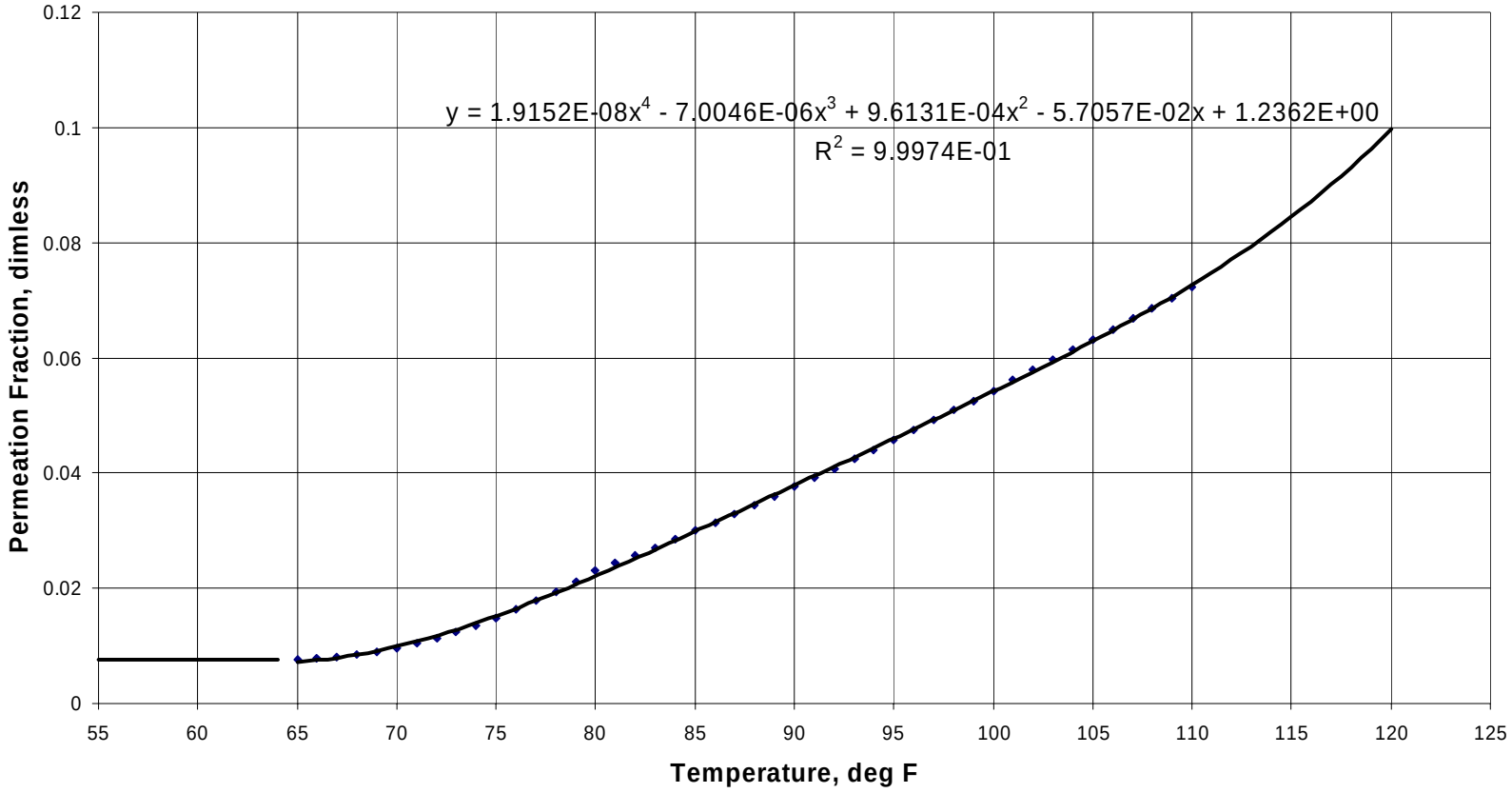
Running Loss Permeation Fraction

- Evaluated at ambient temperature
- Process-specific fraction permeation (PERMfr). Ratio of 90% of resting loss to hourly running loss.
- Weighted average trip length about 15 minutes. 15-minute run loss value compared to resting loss.

Running Loss and Resting Loss for Normal Enhanced Evap Cars



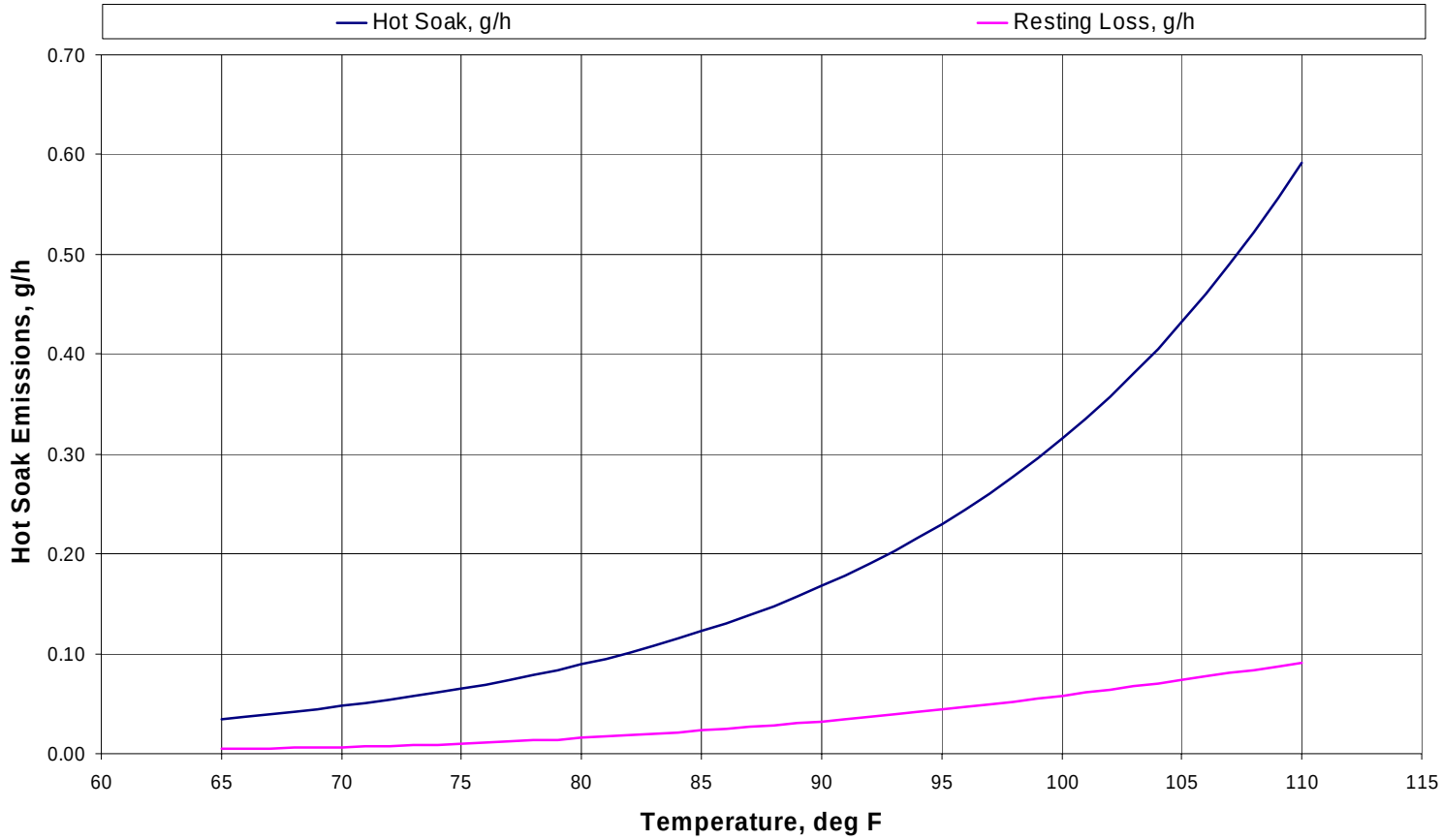
Running Loss Permeation Fraction for Normal Enhanced Evap Cars



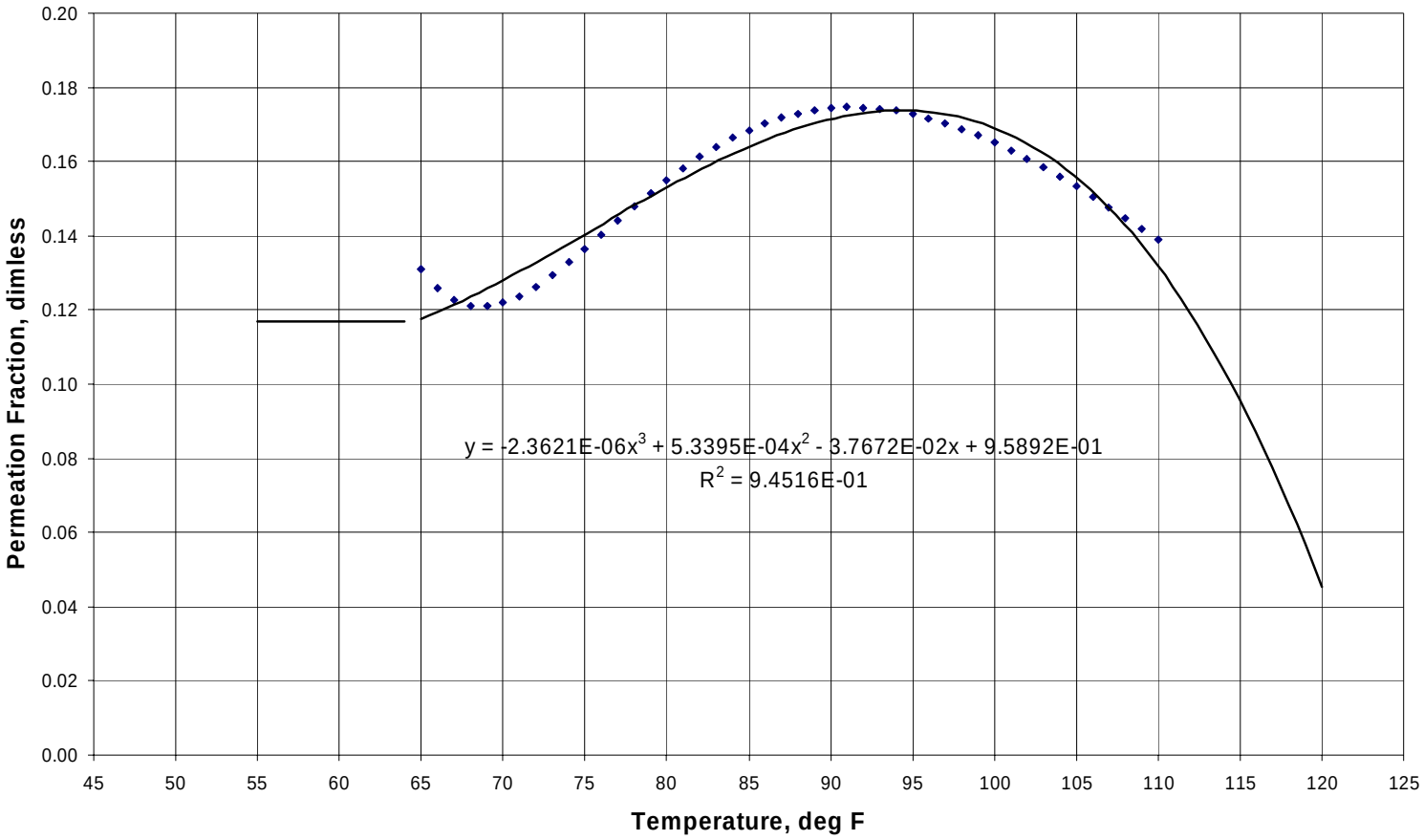
Hot Soak Permeation Fraction

- Evaluated at ambient temperature.
- Process-specific fraction permeation (PERMfr). Ratio of 90% of resting loss to hourly average hot soak.

Hot Soak and Resting Loss for Normal Enhanced Evap Cars



Hot Soak Permeation Fraction for Normal Enhanced Evap Cars



Off-Road Sources Data/Methodology

- 5 new lawnmowers tested with MTBE and ethanol fuel (5.95 vol %)
- Minute-by-minute test data over the certification temperature profile (65-105^{o}F) for diurnal and resting losses
- Hot Soak tested at 95^{o}F
- No running loss test data
- Gas cans tested (untreated/fluorinated/sulfonated)

Off-Road Equipment Evaporative Ethanol Permeation Augmentation

Temperature Profile	Ethanol Augmentation
Equipment Fuel tanks*	
Summer Episodic	1.38
Summer Average	1.27
Winter Average	1.19
Annual Average	1.24
Untreated Gas Can	1.56
Fluorinated Plastic Cans	2.04
Sulfonated Plastic Cans	1.38

* Plastic shown. Steel tanks are assumed to be 70% of these values

Onroad Ethanol Permeation Inventory Effects (SCAB 2005 Summer Ozone Episode)

		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
Running Loss	ton/d	6.7	64.6	43.2	114.5	7.3	64.9	43.5	115.7	1.2
Hot Soak	ton/d	1.5	14.5	9.8	25.8	2.4	14.5	9.9	26.8	1.0
Totals	ton/d	16.7	94.7	66.2	177.6	25.6	96.3	67.2	189.1	11.5

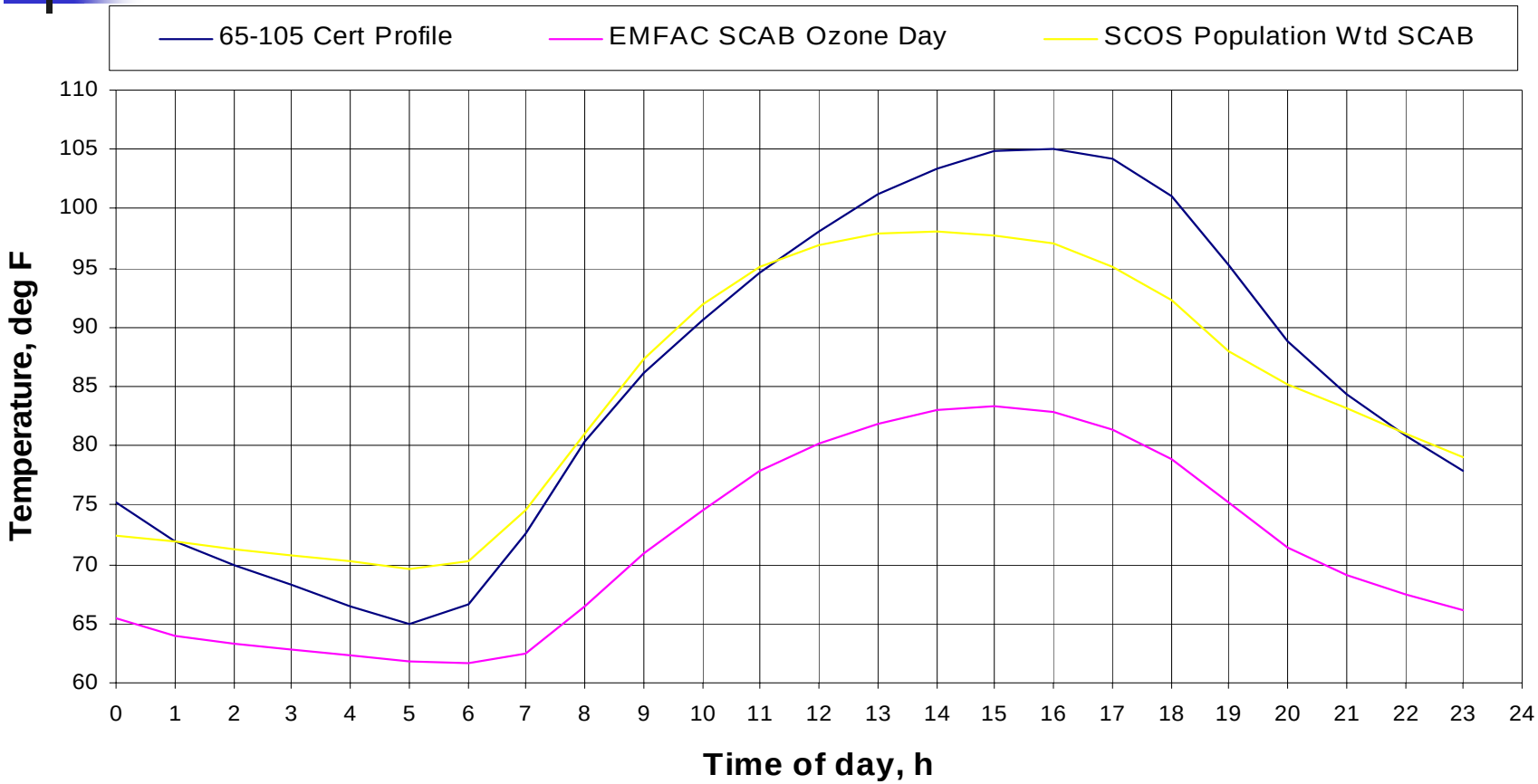
Note: Still Preliminary. Based on EMFAC 2007 Working Draft. Subject to VMT changes from COGs

Off-Road
Results of Preliminary Calculations
(2004 Summer Average)

Area	Evap Emission (MTBE) Tons per day	Evap Emission (Ethanol) Tons per day	Difference Tons per day
Statewide	86.6	107.4	20.8
South Coast	30.8	38.2	7.4
San Joaquin Valley	8.4	10.4	2.0

Includes emissions from small and large off-road equipment and recreational marine engines

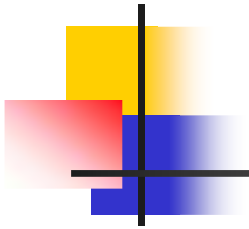
Diurnal Temperature Profiles



Onroad Ethanol Permeation Inventory Effects (SCAB 2005 SCOS Temperatures)

		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
Running Loss	ton/d	7.7	66.2	49.0	122.9	8.3	67.6	50.1	126.0	3.1
Hot Soak	ton/d	2.4	20.4	15.3	38.1	3.2	21.6	16.3	41.1	3.0
Totals	ton/d	24.9	120.7	84.7	230.3	43.7	127.8	88.3	259.8	29.5

Note: Still Preliminary. Based on EMFAC 2007 Working Draft



End of Presentation

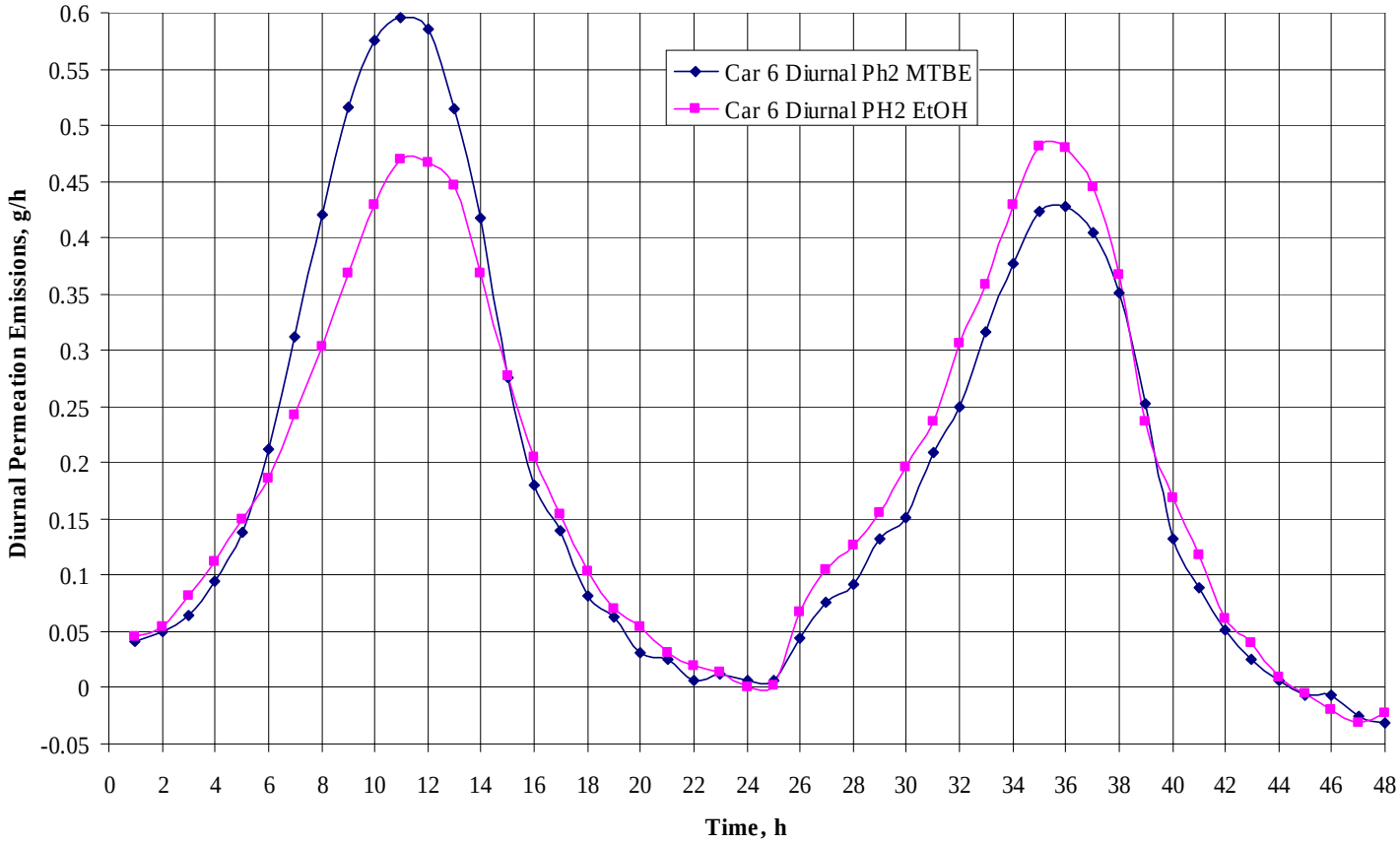
Questions?

E65 Diurnal Results

MY		MTBE	EtOH	Gaso	Age		delta	ratio
		g/d	g/d	g/d	y		g/d	
2001		0.2	0.76	0.22	3		0.52	3.17
2000		0.6	1.43	0.58	4		0.79	2.23
1999		0.3	1.37	0.33	5		1.08	4.72
1997		0.6	2.25	1.13	7		1.62	3.57
1995		9.2	11.65	11.81	9		2.45	1.27
1993	*	3.7	4.89	3.72	11		1.19	1.32
1991		1.2	2.25	1.91	13		1.01	1.81
1989		1.0	2.63	0.82	15		1.67	2.74
1985		2.0	4.67	1.77	19		2.71	2.38
1978		1.9	3.74	2.3	26		1.82	1.95
		20.8	35.6	24.6	112	tot g/d	14.9	2.52
		2.1	3.6	2.5	11	g/d avg	1.5	1.72
		86.6	148.5	102.5		mg/h	61.9	
8 normals		7.9	19.1	9.1		tot g/d	11.2	
		1.0	2.4	1.1		g/d avg	1.4	2.42
2 moderates		12.9	16.5	15.5		tot g/d	3.6	
		6.5	8.3	7.8		g/d avg	1.8	1.28

ARB grouped Cars 5&6 as moderates

E65 Car 6 Diurnal



Onroad Ethanol Permeation Inventory Effects (SCAB 2005 Summer Ozone Episode)

		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

Note: Still Preliminary. Based on EMFAC 2007 Working Draft

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