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MEMORANDUM

SUBJECT: Methodology for Developing Inventory Reductions Used in Ozone Modeling

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TO: Docket A-97-10

An analysis on the effect of proposed Tier 2 and Sulfur standards on ambient ozone levels in the 37-state OTAG region is presented in Chapter 3 of the Tier 2 Regulatory Impact Analysis (RIA). This analysis required running two simulations of the OTAG photochemical grid model, a base case (without Tier 2/Sulfur controls) and a control case (emission reductions that reflect standards very similar to the proposed Tier 2/Sulfur controls). The effects of the control program on ambient ozone levels were then evaluated by comparing the modeling results of the two cases. OTAG model results for 2007 which reflect the OTAG SIP Call final rule (also known as the Regional Ozone Transport Rule, or ROTR) served as the base case. The NOx and VOC reductions evaluated for the proposed Tier 2 and Sulfur program control cases were expressed as a percentage reduction from the baseline 2007 on-highway mobile source inventory. These percentage reductions (defined for the remainder of the document as percent reductions from all on-highway mobile sources) were applied to on-highway emissions in the baseline case everywhere in the modeling domain, to generate the ozone effects discussed in the RIA.[1]

The OTAG model was run with four unique sets of percent reductions, termed OMS1 through 4. OMS1 and 2 were generated for the purpose of providing initial exploratory results as to the relative merit of NOx and VOC control in reducing ambient ozone levels. OMS3 and 4 were generated subsequent to OMS1 and 2, and more closely reflect the Tier 2 and Sulfur program as proposed. The purpose of this memo is to document how the percent reductions in

[1]The application of percent reductions is the subject of a separate memorandum from Harvey Michaels to Docket A-97-10 ("Photochemical Air Quality Simulations in Support of Tier 2/Sulfur"), and thus is not covered in detail in this document.

on-highway emissions were developed for the OMS1 through 4 scenarios, and the proposed Tier 2 and Sulfur program. The overall approach used to calculate the percent reductions involved the following steps: 1) absolute emission reductions (either in terms of grams per mile or tons) were generated using updated versions of EPA's on-highway inventory model MOBILE, in terms of 2007 emissions; 2) percent reductions were then calculated by dividing these absolute emission reductions by a simplified estimate of the baseline OTAG on-highway emission inventory in 2007. As described in the technical memorandum entitled "Photochemical Air Quality Simulations in Support of Tier 2/Sulfur", the percent reductions calculated from Steps (1) and (2) were applied directly to on-highway emissions in the OTAG model for the analysis of control scenario ozone effects.

Percent reductions for OMS1 and 2 were developed earlier and used a different approach than OMS3 and 4; the two sets of scenarios are thus discussed separately.

Generation of OMS1 and 2 Percent Reductions

The model used to generate percent reductions for OMS1 and 2 is known as the Modified MOBILE5b model, developed in support of the draft Tier 2 Study published in April 1998.[2] This model was EPA's initial attempt to reflect changes planned for MOBILE6, including revised in-use emission levels, off-cycle effects, fuel sulfur effects and growth in LDT sales. For OMS1 and 2, gram per mile emission factors (EFs) were used as the basis for determining percent reductions. A single model run was used to represent average 2007 pre-control emissions within the 37-state OTAG modeling domain; this run reflected the effects of NLEV in an area outside of the Ozone Transport Region (OTR) with I/M, RFG and the Supplemental Federal Test Procedure (SFTP) requirement. On-highway emissions under the 2007 pre-control scenario were expressed as composite gram per mile EFs (one each for NOx and VOC), which represented the average gram per mile emission factor across all vehicle classes weighted by the relative contribution to total vehicle miles traveled (VMT).

The post-control case was developed by modeling the impact of continued fleet turnover through 2020, and then reducing these emissions by specified percentages to simulate the effects of potential vehicle and fuel controls. Post-control EFs were generated for OMS1 according to the following steps:

1) Fleet average NOx EFs were generated for gasoline light-duty vehicles and trucks for the pre-control case in 2020. These emission factors were then reduced by 50 percent to simulate more stringent control, resulting in the post-control EFs. Post-control VOC EFs were unchanged from 2007 pre-control levels for the OMS1 scenario.
2) The post-control NOx EFs generated in Step (1) were recombined with 2007 pre-control emission factors from all other vehicle classes (light-duty diesel, heavy-duty, and

[2] Koupal, J. and Rykowski, R., "Methodology for Modifying MOBILE5b in the Tier 2 Study", EPA Report No. EPA420-R-98-004, April 1998

motorcycle), resulting in a composite post-control on-highway EF which reflected the effects of additional vehicle and fuel control.

Post-control EFs were generated for OMS2 according to the following steps:

1) Fleet average exhaust VOC[3] EFs were generated for gasoline light-duty vehicles and trucks for the pre-control case in 2020; these EFs were combined with the 2007 pre-control evaporative VOC EFs, resulting in post-control VOC EFs. Post-control NOx EFs were unchanged from 2007 pre-control levels for the OMS2 scenario.
2) The post-control VOC EFs generated in Step (1) were recombined with 2007 pre-control emission factors from all other vehicle classes (light-duty diesel, heavy-duty, and motorcycle), resulting in a composite on-highway EF in 2007 which reflected the effects of additional vehicle and fuel control.

For both OMS1 and OMS2, absolute emission reductions were generated by subtracting the control case 2007 EFs from Step (2) from the 2007 pre-control EFs, resulting in an absolute gram per mile reduction across all on-highway vehicles. Percent reductions were then calculated by dividing this absolute reduction by baseline on-highway EFs in 2007 *as calculated by MOBILE5b*. This latter step was necessary because the on-highway emission estimates used in the OTAG model are based on MOBILE5, and hence any projected reductions expected from additional vehicle and fuel controls must be expressed in terms of reductions from a MOBILE5 baseline. In effect, the MOBILE5b results used for this analysis are an approximation of OTAG's 37-state on-highway inventory. For OMS1 and 2, only one Region/IM/Fuel scenario (i.e. non-OTR with I/M and RFG) was used to approximate the entire 37-state OTAG modeling domain; this element of the analysis was further refined in the generation of OMS3 and 4 percent reductions.

The percent reductions generated for OMS1 (NOx control only) and OMS2 (VOC control only) as outlined above are shown in Table 1. The "Pre-control" rows are 2007 emission factors by vehicle class for the pre-control case. The "Post-control" rows are emission factors generated by Step (1) above. The column entitled "EF - All Other Classes" reflects the average emission factor across the light-duty diesel, heavy-duty and motorcycle classes, which (according to Step (2) above) were not changed between the pre-control and post-control case. "Composite On-Highway EF" is the average of the Gasoline Light-Duty EFs and the EFs from all other classes, weighted by VMT contribution.

[3]NMHC and VOC were assumed to be equal for this analysis.

Table 1: NOx and VOC Percent Reductions Used In OMS1 and 2						
Pollutant	Scenario	Gasoline Light-Duty EF (gram/mile)			EF - All Other Classes	Composite On-Highway EF
		Vehicle	Truck < 6000 lbs	Truck > 6000 lbs		
NOx	Pre-Control	0.73	1.17	1.56	5.31	1.52
	Post-Control	0.20	0.35	0.37	5.31	0.88
	MOBILE5b Baseline On-Highway EF =					1.18
	Baseline EF - Control EF =					0.64
	Percent Reduction (OMS1) =					**54.2%**
VOC	Pre-Control	0.46	0.72	1.00	1.84	0.78
	Post-Control	0.28	0.44	0.68	1.84	0.58
	MOBILE5b Baseline On-Highway EF =					0.66
	Baseline EF - Control EF =					0.20
	Percent Reduction (OMS2) =					**30.3%**

As shown, OMS1 reflected a 54.2 percent reduction in on-highway NOx emissions, and no reduction in VOC emissions; OMS2 reflected a 30.3 percent reduction in on-highway VOC emissions, and no reduction in NOx emissions.

Generation of OMS3 and 4 Percent Reductions

Subsequent to the Tier 2 Study, the light-duty component of the Modified MOBILE5b model was replaced with an analysis tool known as the Tier 2 Model.[4] The Tier 2 Model incorporated updates of in-use emission estimates, off-cycle effects, fuel sulfur effects and truck market share growth more in line with those planned for MOBILE6. The Tier 2 Model also allowed computation of emissions in terms of total tons produced in selected regions (including the 37-state OTAG modeling domain) across the pre-control and post-control scenarios, by a more precise accounting for regional control programs (NLEV, I/M and RFG). The Tier 2 Model only generates light-duty exhaust emissions, however; emission reductions are also projected for NOx and exhaust VOC on heavy-duty vehicles due to sulfur control, and evaporative VOC emissions due to light-duty evaporative control. Two additional updated versions of MOBILE5b were developed in support of the Tier 2 and Sulfur rulemaking to assess

[4]Koupal, J. "Development of Light-Duty Emission Inventory Estimates in the Notice of Proposed Rulemaking for Tier 2 and Sulfur Standards", EPA Report No. EPA420-R-99-005, March 1999

these benefits.[5,6] Total emissions reductions projected to result from the proposed Tier 2 and Sulfur standards were developed across three updated inventory estimation tools. Consistent with the procedure used for the OMS1 and 2 cases, these results were expressed as percentage reductions from a MOBILE5b-derived baseline.

Aside from the inclusion of heavy-duty exhaust and light-duty evaporative emission reductions, the primary differences between the methodology used to generate percent reductions for OMS1 and 2 and OMS3 and 4 were a) the reductions were based on actual tons, rather than emission factors, and b) these tons were developed to more precisely reflect emissions over the summer months in the 37-state OTAG modeling domain. The latter was accomplished by generating raw emission estimates across several region and control program combinations, which were then combined based on population weighting factors to derive the appropriate regional mix. Up to eight control program combinations were modeled to include permutations of region, I/M program and fuel program. These combinations are shown in Table 2, for the Tier 2 Model, MOBILE5b, and Evaporative MOBILE5b.

Table 2: Region/Control Program Combinations Run for Tier 2 Model, MOBILE5b and Evaporative MOBILE5b

Region	IM/RFG	IM/No RFG	No IM/RFG	No IM/No RFG
OTR	Tier 2 Model MOBILE5b	Tier 2 Model MOBILE5b	Tier 2 Model	Tier 2 Model MOBILE5b
Non-OTR	Tier 2 Model MOBILE5b	Tier 2 Model MOBILE5b	Tier 2 Model	Tier 2 Model MOBILE5b
North	Evap MOBILE5b	Evap MOBILE5b	Evap MOBILE5b	Evap MOBILE5b
South	Evap MOBILE5b	Evap MOBILE5b	Evap MOBILE5b	Evap MOBILE5b

The development of emission estimates in terms of summer tons in the 37-state OTAG modeling domain required combination of these control program scenarios into a single emission result. This step was performed using population weightings which reflected the fraction of total population residing under a given control program scenario within the 37-state OTAG modeling domain (for this analysis, population fraction was used as a surrogate for VMT fraction).[7] These

[5]"Development of Heavy-Duty Gasoline Emissions Inventories for the Tier 2/Sulfur NPRM", Memorandum from John Koupal to Docket A-97-10

[6]"A Modified Version of MOBILE5 for Evaluation of Proposed Tier 2 Evaporative Emission Standards", Memorandum from David J. Brzezinksi to Docket A-97-10

[7] "Nationwide and Regional Populations Fractions", Memorandum from David Korotney to Docket A-97-10

population weightings are shown in Table 3.

Table 3: Population Weighting Factors: 37-State OTAG Region (Summer Months)					
Model	**Region**	**IM / RFG**	**IM / No RFG**	**No IM / RFG**	**No IM / No RFG**
Tier 2 Model	OTR	0.191	0.075	0.017	0.035
	Non-OTR	0.079	0.122	0.004	0.476
MOBILE5b	OTR	0.195	0.077	-	0.036
	Non-OTR	0.081	0.125	-	0.486
Evaporative MOBILE5b	North	0.135	0.099	0.011	0.256
	South	0.135	0.099	0.011	0.256

Because I/M and NLEV do not apply to heavy-duty vehicles, a simplified approach was used to generated composite 37-state summer emissions for these vehicles based solely on RFG fraction. Baseline emissions for these vehicles were generated using an in-use sulfur level of 278 ppm, which represents the weighted average of summertime RFG sulfur (150 ppm) and non-RFG sulfur (330) ppm. This level was generated using an RFG fraction of 0.29 derived from the weighting factors presented above.

Computing emissions in terms of tons required estimates of vehicle miles traveled (VMT) during the summer months of 2007 and 2020 in the OTAG modeling domain. These estimates were derived by multiplying annual VMT across the 47-state analysis region (U.S. minus California, Alaska and Hawaii)[8] by a factor of 0.375, based on a) the estimate that 90 percent of the population in the 47-state region live within the 37-state OTAG modeling domain, and b) the summer months (May through September) comprise 5/12 (42 percent) of an entire year. The resulting VMT estimates are shown in Table 4.

Table 4: VMT in 37-State OTAG Region (Summer Months) - Millions of Miles		
	2007	**2020**
LDVs and LDTs	923,715	1,194,768
Heavy-Duty Vehicles	23,526	31,087

[8]Koupal, J. "Development of Light-Duty Emission Inventory Estimates in the Notice of Proposed Rulemaking for Tier 2 and Sulfur Standards", EPA Report No. EPA420-R-99-005, March 1999, Appendix K

Using these VMT estimates, tons of NOx and VOC produced for the pre-control and post-control scenarios were generated in 2007 and 2020 using the updated inventory models. Absolute tonnage reductions could then by derived, as shown in Table 5.

Table 5: Tons Reduced in 37-State OTAG Region (Summer Months)

		NOx		VOC	
		2007	**2020**	**2007**	**2020**
LDV/LDT Exhaust	Pre-Control	1,189,700	1,182,826	455,683	354,262
	Post-Control	900,976	381,451	411,588	259,889
	Reduced	**288,724**	**801,375**	**44,095**	**94,373**
LDV/LDT Evap	Pre-Control	-	-	474,537	439,661
	Post-Control	-	-	470,058	411,155
	Reduced	-	-	**4,479**	**28,506**
Heavy-Duty	Pre-Control	95,430	62,094	83,990	82,722
	Post-Control	86,017	53,011	81,893	81,213
	Reduced	**9,413**	**9,083**	**2,097**	**1,509**
Total Tons Reduced		**298,137**	**810,458**	**50,671**	**124,388**

The next step in computing percent reductions across all on-highway mobile sources was to establish an approximation of the baseline on-highway estimates used in the OTAG modeling. A simplified approach was required for this step, since replication of the county-by-county inventories used on the OTAG model was outside the scope of this analysis. However, it was important to generate a baseline which replicated the temperature and speed conditions assumed in the generation of absolute tonnage reductions presented above, in order to provide a consistent basis of comparison between the approximated OTAG baseline and the tonnage reductions.

As mentioned, the OTAG model relies on MOBILE5 for on-highway mobile source inputs. Baseline emission levels for all on-highway vehicles were therefore developed by running MOBILE5b over the six pertinent control scenario combinations from Table 2, and combined according to the population weighting factors presented. MOBILE5b was run using inputs for I/M, heavy-duty emission rates and NLEV phase-in schedule intended to replicate those used in the OTAG model.[9] To match the conditions used in the derivation of tonnage emission reductions, the daily maximum and minimum temperatures were set to 72° and 96° F, and the

[9]"Ozone Transport Assessment Group Emissions Inventory Development Report, Volume 3: Projections and Controls", Draft Report from E.H. Pechan & Associates, Inc. to EPA Office of Air Quality Planning and Standards, EPA Contract No. 68-D3-0035, Work Assignment No. III-101, June 1997

average speed was set to 24.6 mph.[10]

Resulting MOBILE5b output in 2007 was expressed in terms of grams per mile across all on-highway vehicles, reflecting the appropriate mix of control programs within the 37-state OTAG modeling domain. A total tonnage number was generated by applying an estimate of total on-highway VMT. This VMT estimate was based on a 47-state estimate of annual VMT in 2007 presented in EPA's Trends Report, again multiplied by 0.375 to reflect 37-state summer VMT. The resulting VMT estimate was applied to the composite on-highway emission factor generated from MOBILE5b, resulting in total on-highway tons in summer 2007 under the baseline scenario, shown in Table 6.

Table 6: Approximation of Baseline 2007 On-Highway Emissions in 37-State OTAG Region (Summer Months)

	37-State Summer MOBILE5b On-Highway Emission Factor (grams/mile)	37-State Summer On-Highway VMT (Millions of Miles)	37-State Summer Tons
NOx	1.44	1,017,083	1,614,418
VOC	1.06	1,017,083	1,188,391

From this baseline, the final step was the generation of percent reductions across all-highway vehicles using the absolute reductions from 2007 and 2020. These reductions were applied to post-ROTR on-highway vehicle emissions for each grid cell to develop the gridded inventories used in the OMS3 and 4 model runs. These percentages were computed by dividing the total tons reduced from Table 4 by the total on-highway baseline tonnages from Table 5, as shown in Table 7.

Table 7: Percent Reductions For OMS3 and 4

	OMS4 (2007)		OMS3 (2020)	
	NOx	**VOC**	**NOx**	**VOC**
Baseline	1,614,418	1,188,391	1,614,418	1,188,391
Tons Reduced	298,137	50,571	810,458	124,388
Percent Reduction	**18.5%**	**4.3%**	**50.2%**	**10.5%**

Proposed Tier 2/Sulfur Standards

[10]Specific MOBILE5b inputs are generally identical to those presented in "Methodology for Modifying MOBILE5b in the Tier 2 Study" (EPA Report No EPA420-R-98-004); the only exception is the application of "appropriate" I/M, which was applied to LEVs but not Tier 1 vehicles for this analysis.

The proposed Tier 2 vehicle standards were revised subsequent to the development of the OMS3 and 4 scenarios. Updated percent reductions were generated which reflected the Tier 2 and Sulfur standards as currently proposed; percent reductions based on 2010 benefits were also generated for this case. All are shown in Table 8.

Table 8: Percent Reductions For Proposed Tier 2 and Sulfur Standards

	2007		**2010**		**2020**	
	NOx	**VOC**	**NOx**	**VOC**	**NOx**	**VOC**
Baseline	1,614,418	1,188,391	1,614,418	1,188,391	1,614,418	1,188,391
Tons Reduced	292,166	47,835	433,613	64,442	807,625	121,215
Percent Reduction	**18.1%**	**4.0%**	**26.9%**	**5.4%**	**50.0%**	**10.2%**

A final estimate used in the Tier 2 RIA is the percent reduction in on-highway NOx emissions projected to occur between 2007 and 2010 under the "Without Tier 2/Sulfur" scenario (4.3 percent). This estimate was used in the calculation of ambient ozone levels in 2010 without Tier 2 or sulfur control, to provide a basis of comparison with controlled levels in this year. This figure was estimated by subtracting summer tons reduced in the 37-state OTAG region between 2007 and 2010 for LDVs and LDTs under the baseline scenario (roughly 69,000), and dividing this amount by the approximated OTAG on-highway baseline in Table 6.

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