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Estimation of Motor Vehicle Toxic Emissions and Exposure in Selected Urban Areas

Volume I

DRAFT

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Assessment and Modeling Division
Office of Mobile Sources
U.S. Environmental Protection Agency

Prepared for EPA by
Sierra Research, Inc.
Radian International Corporation
Energy and Environmental Analysis, Inc
EPA Contract No. 68-C7-0051
Work Assignment No. 0-07

NOTICE

This technical report does not necessarily represent final EPA decisions or positions. It is intended to present technical analysis of issues using data which are currently available. The purpose in the release of such reports is to facilitate the exchange of technical information and to inform the public of technical developments which may form the basis for a final EPA decision, position, or regulatory action.

Estimation of Motor Vehicle Toxic Emissions and Exposure in Selected Urban Areas

Volume I

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1. SUMMARY

Under Work Assignment 0-07 of U.S. Environmental Protection Agency (EPA) contract #68-C7-0051, Sierra Research, Inc. (Sierra), in conjunction with subcontractors Radian International Corporation (Radian) and Energy & Environmental Analysis, Inc. (EEA), has performed a number of tasks related to the assessment of motor vehicle air toxics emissions, exposure, and risk assessment. As described below, emissions and exposure estimates were prepared for the following air toxics: benzene, acetaldehyde, formaldehyde, 1,3-butadiene, MTBE, and Diesel particulate. The analysis was performed for nine selected urban areas in the U.S. under a variety of control scenarios. Estimates were prepared for calendar years 1990, 1996, 2007, and 2020. Although risk estimates were not prepared as part of this study, the modeling framework to perform those calculations, with the unit risk factor for each toxic as a variable input, was developed.

Modeled Areas and Control Scenarios

This work assignment was carried out to support possible regulatory action required by Section 202(l) of the Clean Air Act (as amended in 1990), which calls for EPA to promulgate regulations containing reasonable requirements to control hazardous air pollutants (HAPs) from motor vehicles and motor vehicle fuels. In addition, the results may also be used to estimate cancer risk in the regulatory impact analysis for proposed Tier 2 tailpipe emissions standards. Under this work assignment, on-road motor vehicle air toxics emissions and exposure estimates were prepared for nine urban areas consisting of Chicago, Denver, Houston, Minneapolis, New York City, Philadelphia, Phoenix, Spokane, and St. Louis. Modeling was performed for 1990, 1996, 2007, and 2020, and separate estimates were prepared for winter, spring, summer, and fall. The forecast years include four control scenarios that were defined in consultation with EPA:

0. Baseline fuels and emission rates, assuming the implementation of a National Low-Emission Vehicle (NLEV) program;

1. Baseline emission factors with an assumed national gasoline regulation limiting sulfur levels to 40 ppm;

2. Scenario 1 with more stringent tailpipe hydrocarbon emission standards for light-duty cars and trucks (i.e., reflecting possible Tier 2 standards); and

3. Scenario 2 with an assumed increase in light-duty Diesel truck implementation equivalent to 50% of total light-duty truck sales beginning in model year 2004.

Methodology

Emissions Estimates - The methodology used to prepare the emission estimates for this study was similar to the approach used by EPA in its development of toxics emission rates for the 1993 Motor Vehicle Related Air Toxics Study (MVRATS). In that approach, the MOBILE model is used to generate total organic gas (TOG) emissions from on-road motor vehicles by vehicle class and model year. Toxics fractions, developed as a percentage of the toxic compound of interest contained in TOG emissions, are then applied to the MOBILE-based TOG gram per mile (g/mi) results to arrive at toxic emission rates in g/mi or milligrams per mile (mg/mi). The toxics fractions are developed as a function of vehicle type (e.g., light-duty versus heavy-duty), fuel type (gasoline versus Diesel), and technology type (e.g., non-catalyst versus catalyst).

Although there are similarities between the emissions methodology used in the 1993 MVRATS and the methodology used in this study, there are also a number of areas in which improvements were made. These include the following.

- The on-road motor vehicle TOG emission rates were based on a version of MOBILE5b that EPA recently modified for the Tier 2 Study to incorporate updates to the model expected with the release of MOBILE6. These updates included revised base emission rate equations, incorporation of off-cycle emissions effects, revised fleet characteristics, and revised fuel effects.

- The emissions response (both in terms of TOG and toxics) of newer technology vehicles to changes in fuel parameters was based on an evaluation performed with the Complex model for reformulated gasoline. This model was not available at the time the 1993 MVRATS was completed.

- Instead of applying a single toxics fraction to each technology or model year, the emissions impacts of particular fuel formulations on late-model vehicles were assessed separately for normal and high emitting vehicles. The approach used to implement this methodology relied on the development of "toxic-TOG curves" that plotted the target fuel toxic emission rate (in mg/mi) against the base fuel TOG emission rate (in g/mi). Different toxic-TOG curves were developed for each of the 72 fuel formulations[*] investigated in this study. The MOBILE model was then revised to apply the calculated TOG emission rate to the toxic-TOG curve to determine the corresponding toxic emission rate.

Because of the vast number of model runs required in this effort, the process was automated as much as possible. Software was developed to create area-specific input files and to process the model output into a format that could be easily used in the ensuing exposure calculations.

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[*] Nine urban areas were evaluated, each having different fuel formulations in winter and summer. In addition, three different formulations were used to reflect the 1990, 1996, and 2007/2020 baseline runs, with a fourth used for the national 40 ppm sulfur scenario. Thus, a total of 72 different fuels (9 areas × 2 seasons × 4 fuels) were evaluated in this project.

Exposure Estimates - Once the toxics emission rates were developed, toxics exposure was estimated according to the following formula:

$$TOX_{Exposure(\mu g/m3)} = [CO_{Exposure(\mu g/m3)}/CO_{EF(g/mi)}]_{1990} \times TOX_{EF(g/mi)}$$

where TOX reflects one of the six toxic pollutants considered in this study. Because some of the toxic pollutants evaluated in this study (e.g., 1,3-butadiene) have a different photochemical reactivity than CO, the exposure concentrations were adjusted to account for atmospheric transformation. In addition, because the CO ratios are based on the 1990 calendar year, an adjustment was made to account for the increase in VMT relative to 1990. These adjustments were developed in consultation with EPA.

The 1990 CO exposure estimates above were based on recent modeling performed under contract to EPA with the Hazardous Air Pollutant Exposure Model (HAPEM). These estimates were provided to the study team for each of the modeled urban areas and represent only that portion of CO exposure attributable to on-road motor vehicles. Separate exposure estimates were provided by quarter and for three different demographic groups: (1) total population, (2) outdoor workers, and (3) children 0 to 17 years of age. Outdoor workers were selected because they represent the highest exposed demographic group, while children are generally considered a very sensitive demographic group.

Similar to the toxics emissions estimates, the 1990 CO emission factors were based on a modified version of MOBILE5b that incorporated many revisions expected to be implemented with MOBILE6. This included revised base emission rates, incorporation of off-cycle effects, and revised oxygenated fuel effects.

The 1990 CO emission factors, toxics emission factors (all calendar years and scenarios), and 1990 CO exposure estimates were compiled in a FORTRAN routine to generate exposure estimates according to the formula above. Estimates are prepared according to urban area, calendar year, season, control scenario, vehicle class, demographic group, and toxic compound.

Risk Assessment - Although the original work plan drafted for this study included the analysis of cancer risk, EPA requested that cancer risk estimates not be prepared at this time because work is still underway to develop appropriate unit risk factors to assign to each toxic. Instead, Sierra was instructed to develop a modeling methodology that would allow EPA to input appropriate unit risk factors at a later date. This was accomplished within the FORTRAN routine developed to calculate exposure.

Within the exposure model, estimates of individual cancer risk are calculated with the following formula:

$$CAN_{Ind} = TOX_{Exposure\text{-}Adj\ (\mu g/m3)} \times (UR / YPL)$$

where $TOX_{Exposure\text{-}Adj\ (\mu g/m3)}$ is the toxic exposure estimates adjusted for VMT growth and atmospheric transformation; UR is the unit risk in cancer cases or deaths per person exposed in a lifetime to 1 μg/m^3 of the toxic compound of interest; and YPL is years per lifetime (typically assumed to be 70 years).

To calculate the total cancer cases for the population, the individual cancer risk defined above was simply multiplied by the population subject to the toxic compound exposure, i.e.,

$$CAN_{Pop} = CAN_{Ind} \times \text{Population}$$

The above calculations are carried out for each of the modeled urban areas investigated in this study.

Results

Toxics Emissions Estimates - The results of the toxics emissions analysis are presented in Section 6 of this report, and a summary of annual-average toxic emission rates is given in Table 1-1 for Chicago and Phoenix. Reviewing the fleet-average toxics emission factors in that table, the following observations can be made:

- Significant reductions in fleet-average toxics emissions are observed between 1990 and 2020 with no further vehicle or fuel controls. This is a result of fleet-turnover resulting in full implementation of the federal emission control regulations currently on the books.

- Implementation of Scenario 1 (national 40 ppm sulfur limit) has no impact on the Phoenix runs. That is because it was assumed that Phoenix would continue to use CARB "Cleaner Burning Gasoline" (CBG), which already has sulfur levels below 40 ppm on average.

- For the Chicago runs, Scenario 1 has the largest impact on benzene and 1,3-butadiene emissions. Aldehyde emissions are less affected under this scenario.

- Because it is assumed that gasoline dispensed in Chicago will use either ETBE or ethanol as an oxygenate, MTBE emission rates are zero for all scenarios.

- Moderate reductions are observed with Scenario 2 (potential Tier 2 controls) in 2007. However, by 2020 fleet-turnover impacts result in fleet-average toxic emission reductions on the order of 15% to 25%.

- Implementation of Scenario 3 (increased light-duty Diesel truck sales) results in reductions in benzene, acetaldehyde, 1,3-butadiene, and MTBE (where used). However, formaldehyde emissions show a slight increase. Obviously, Diesel PM emissions increase substantially under this scenario.

Table 1-1
Annual Average On-Road Motor Vehicle Toxics Emission Rates for Chicago and Phoenix
(Units: mg/mi)

Pollutant	Area	Scenario	Calendar Year 1990	1996	2007	2020
Benzene	Chicago	Base	119.7	53.3	24.2	14.9
		Sc#1	---	---	23.0	13.8
		Sc#2	---	---	21.9	10.4
		Sc#3	---	---	19.6	8.3
	Phoenix	Base	134.4	71.2	16.7	10.1
		Sc#1	---	---	16.7	10.1
		Sc#2	---	---	16.0	7.7
		Sc#3	---	---	14.6	6.4
Acetaldehyde	Chicago	Base	17.9	17.8	7.4	4.4
		Sc#1	---	---	7.2	4.2
		Sc#2	---	---	6.9	3.4
		Sc#3	---	---	6.6	3.2
	Phoenix	Base	16.3	14.2	3.8	2.4
		Sc#1	---	---	3.8	2.4
		Sc#2	---	---	3.7	2.1
		Sc#3	---	---	3.9	2.2
Formaldehyde	Chicago	Base	55.2	29.4	13.1	8.0
		Sc#1	---	---	13.1	8.0
		Sc#2	---	---	12.8	6.8
		Sc#3	---	---	13.0	6.9
	Phoenix	Base	58.9	32.0	13.1	7.7
		Sc#1	---	---	13.1	7.7
		Sc#2	---	---	12.8	6.7
		Sc#3	---	---	13.1	6.9
1,3-Butadiene	Chicago	Base	16.5	7.2	3.0	2.1
		Sc#1	---	---	2.7	1.9
		Sc#2	---	---	2.6	1.6
		Sc#3	---	---	2.6	1.4
	Phoenix	Base	13.7	7.7	2.2	1.6
		Sc#1	---	---	2.2	1.6
		Sc#2	---	---	2.2	1.3
		Sc#3	---	---	2.2	1.3
MTBE	Chicago	Base	0.0	0.0	0.0	0.0
		Sc#1	---	---	0.0	0.0
		Sc#2	---	---	0.0	0.0
		Sc#3	---	---	0.0	0.0
	Phoenix	Base	102.7	4.0	48.0	27.3
		Sc#1	---	---	48.0	27.3
		Sc#2	---	---	47.7	26.1
		Sc#3	---	---	41.5	20.1
Diesel PM	Chicago	Base	93.5	53.6	23.4	17.4
		Sc#1	---	---	23.4	17.4
		Sc#2	---	---	23.4	17.4
		Sc#3	---	---	38.7	41.3
	Phoenix	Base	92.9	61.2	23.4	17.4
		Sc#1	---	---	23.4	17.4
		Sc#2	---	---	23.4	17.4
		Sc#3	---	---	38.7	41.3

Toxics Exposure Estimates - A summary of motor vehicle air toxics exposure is given in Table 1-2 for Phoenix and Chicago. As with the toxic emission rate estimates, motor vehicle air toxics exposures are projected to decrease substantially between 1990 and 2020, even without additional controls on vehicles and fuels. Although the results for all modeled urban areas are not shown in Table 1-2, the benefits of Scenario 1, a national gasoline rule limiting sulfur to 40 ppm, are greatest in areas that do not have a pre-existing reformulated gasoline program such as Minneapolis. Areas with an RFG program show more moderate decreases in motor vehicle toxics exposure, depending on pollutant, as a result of a national gasoline sulfur limit. The more stringent light-duty vehicle emission standards modeled in Scenario 2 in general show greater decreases in toxics exposure than the other control scenarios modeled in this effort, particularly for the 2020 calendar year run. Finally, the increased light-duty Diesel penetration scenario modeled in Scenario 3 results in substantial increases in Diesel particulate exposure levels, although benzene and 1,3-butadiene exposure is decreased. It should be kept in mind that the exposure estimates for acetaldehyde and formaldehyde do not include any adjustments to account for atmospheric transformation.

As discussed above, exposure estimates were prepared for three different demographic groups: total population, outdoor workers, and children 0-17 years of age. (The estimates given in Table 1-2 are for the total population.) The exposure to air toxics for outdoor workers is generally about 20% higher than for the total population, while exposure for children is typically slightly below the total population. This is observed in Table 1-3, which shows the annual-average benzene exposure for the three demographic groups analyzed in this study for Chicago under the control scenarios described above. As seen in the table, benzene exposure is highest for outdoor workers (which is the highest exposed demographic group), while children and the total population show similar levels of exposure.

Finally, Table 1-4 presents annual-average on-road motor vehicle exposure results for benzene for all modeled urban areas. As seen in that table, areas with high benzene exposures in 1990 include Minneapolis, New York, and Phoenix, while Houston and St. Louis fall on the lower end of the scale. Because Minneapolis is not subject to in-use motor vehicle control programs (i.e., inspection and maintenance; reformulated gasoline) as stringent as those in New York, the reduction in exposure levels between 1990 and 2020 is not as great.

Table 1-2
Annual-Average Exposure Results for Chicago and Phoenix
Total Population - All On-Road Vehicles
(Units: ug/m3)

Pollutant	Area	Scenario	1990 CO Ratio	Calendar Year 1990	1996	2007	2020
Benzene	Chicago	Base	8.4	0.997	0.567	0.308	0.235
		Sc#1	8.4	---	---	0.292	0.218
		Sc#2	8.4	---	---	0.279	0.164
		Sc#3	8.4	---	---	0.249	0.131
	Phoenix	Base	14.4	1.923	1.419	0.456	0.378
		Sc#1	14.4	---	---	0.456	0.378
		Sc#2	14.4	---	---	0.437	0.288
		Sc#3	14.4	---	---	0.397	0.236
Acetaldehyde	Chicago	Base	8.4	0.149	0.189	0.094	0.069
		Sc#1	8.4	---	---	0.091	0.066
		Sc#2	8.4	---	---	0.088	0.054
		Sc#3	8.4	---	---	0.084	0.050
	Phoenix	Base	14.4	0.245	0.312	0.101	0.086
		Sc#1	14.4	---	---	0.101	0.086
		Sc#2	14.4	---	---	0.098	0.076
		Sc#3	14.4	---	---	0.103	0.080
Formaldehyde	Chicago	Base	8.4	0.459	0.312	0.167	0.126
		Sc#1	8.4	---	---	0.166	0.125
		Sc#2	8.4	---	---	0.162	0.107
		Sc#3	8.4	---	---	0.165	0.109
	Phoenix	Base	14.4	0.915	0.638	0.352	0.281
		Sc#1	14.4	---	---	0.352	0.281
		Sc#2	14.4	---	---	0.344	0.244
		Sc#3	14.4	---	---	0.350	0.253
1,3-Butadiene	Chicago	Base	8.4	0.100	0.057	0.028	0.025
		Sc#1	8.4	---	---	0.026	0.022
		Sc#2	8.4	---	---	0.025	0.018
		Sc#3	8.4	---	---	0.025	0.016
	Phoenix	Base	14.4	0.150	0.112	0.045	0.044
		Sc#1	14.4	---	---	0.045	0.044
		Sc#2	14.4	---	---	0.044	0.036
		Sc#3	14.4	---	---	0.045	0.034
MTBE	Chicago	Base	8.4	0.000	0.000	0.000	0.000
		Sc#1	8.4	---	---	0.000	0.000
		Sc#2	8.4	---	---	0.000	0.000
		Sc#3	8.4	---	---	0.000	0.000
	Phoenix	Base	14.4	2.109	0.049	1.267	0.994
		Sc#1	14.4	---	---	1.267	0.994
		Sc#2	14.4	---	---	1.260	0.950
		Sc#3	14.4	---	---	1.095	0.731
Diesel PM	Chicago	Base	8.4	0.776	0.566	0.295	0.273
		Sc#1	8.4	---	---	0.295	0.273
		Sc#2	8.4	---	---	0.295	0.273
		Sc#3	8.4	---	---	0.488	0.647
	Phoenix	Base	14.4	1.379	1.205	0.614	0.631
		Sc#1	14.4	---	---	0.614	0.631
		Sc#2	14.4	---	---	0.614	0.631
		Sc#3	14.4	---	---	1.015	1.495

Also Table 7-11

Table 1-3
Annual-Average Exposure Results for Benzene in Chicago by Demographic Group for All On-Road Motor Vehicles (Units: ug/m3)

Demographic Group	Scenario	1990 CO Ratio	Calendar Year			
			1990	1996	2007	2020
Total Population	Base	8.4	0.997	0.567	0.308	0.235
	Sc#1	8.4	---	---	0.292	0.218
	Sc#2	8.4	---	---	0.279	0.164
	Sc#3	8.4	---	---	0.249	0.131
Outdoor Workers	Base	10.1	1.200	0.683	0.371	0.283
	Sc#1	10.1	---	---	0.351	0.262
	Sc#2	10.1	---	---	0.336	0.197
	Sc#3	10.1	---	---	0.300	0.158
Children 0 - 17 Years	Base	8.2	0.980	0.557	0.303	0.231
	Sc#1	8.2	---	---	0.287	0.214
	Sc#2	8.2	---	---	0.274	0.161
	Sc#3	8.2	---	---	0.245	0.129

Table 1-4
Annual-Average Exposure Results for Benzene
Total Population - All On-Road Vehicles
(Units: ug/m3)

Area	Scenario	1990 CO Ratio	Calendar Year 1990	1996	2007	2020
Chicago	Base	8.4	0.997	0.567	0.308	0.235
	Sc#1	8.4	---	---	0.292	0.218
	Sc#2	8.4	---	---	0.279	0.164
	Sc#3	8.4	---	---	0.249	0.131
Denver	Base	8.1	0.922	0.871	0.526	0.430
	Sc#1	8.1	---	---	0.470	0.368
	Sc#2	8.1	---	---	0.452	0.285
	Sc#3	8.1	---	---	0.403	0.227
Houston	Base	6.9	0.787	0.530	0.328	0.244
	Sc#1	6.9	---	---	0.314	0.229
	Sc#2	6.9	---	---	0.303	0.178
	Sc#3	6.9	---	---	0.272	0.145
Minneapolis	Base	11.3	1.923	1.414	1.055	0.978
	Sc#1	11.3	---	---	1.035	0.955
	Sc#2	11.3	---	---	0.995	0.795
	Sc#3	11.3	---	---	0.859	0.587
New York	Base	18.0	2.106	0.903	0.527	0.354
	Sc#1	18.0	---	---	0.503	0.331
	Sc#2	18.0	---	---	0.482	0.246
	Sc#3	18.0	---	---	0.430	0.198
Philadelphia	Base	7.8	1.071	0.642	0.290	0.210
	Sc#1	7.8	---	---	0.273	0.193
	Sc#2	7.8	---	---	0.261	0.145
	Sc#3	7.8	---	---	0.232	0.116
Phoenix	Base	14.4	1.923	1.419	0.456	0.378
	Sc#1	14.4	---	---	0.456	0.378
	Sc#2	14.4	---	---	0.437	0.288
	Sc#3	14.4	---	---	0.397	0.236
Spokane	Base	13.6	1.492	1.194	0.682	0.515
	Sc#1	13.6	---	---	0.600	0.431
	Sc#2	13.6	---	---	0.577	0.330
	Sc#3	13.6	---	---	0.511	0.262
St. Louis	Base	6.0	0.690	0.634	0.302	0.234
	Sc#1	6.0	---	---	0.289	0.218
	Sc#2	6.0	---	---	0.276	0.163
	Sc#3	6.0	---	---	0.246	0.130

2. INTRODUCTION

Background

The 1990 Amendments to the Clean Air Act added requirements for hazardous air pollutants (HAPs), or air toxics. For the most part, those requirements are spelled out in Section 112, which focuses on stationary and area sources. In addition, other sections of the Act include provisions for air toxics. In particular, Section 202(l) contains two requirements specific to motor vehicles:

- By May 15, 1992, EPA was to complete a study of the need for, and feasibility of, controlling emissions of toxic air pollutants associated with motor vehicles and motor vehicle fuels. That study was to focus on the categories of emissions that pose the greatest risk to human health (or about which significant uncertainties remain), including benzene, formaldehyde, and 1,3-butadiene.

- By May 15, 1995, EPA was to promulgate regulations containing reasonable requirements to control HAPs from motor vehicles and motor vehicle fuels. At a minimum, those regulations were to apply to benzene and formaldehyde.

The result of the first directive was the "Motor Vehicle-Related Air Toxics Study," (MVRATS) finalized by EPA in April 1993.[1] Although emission standards specific to air toxics were included in the reformulated gasoline rulemaking promulgated in December 1993,[2] EPA has yet to adopt HAP emissions regulations for motor vehicles required under the second directive above. This work assignment was carried out to support possible regulatory action required by Section 202(l). In addition, the results may also be used to estimate cancer risk in the regulatory impact analysis for proposed Tier 2 tailpipe emissions standards.

Project Scope

Under this work assignment, on-road motor vehicle air toxics emissions, exposure, and cancer risk were estimated for nine urban areas consisting of Chicago, Denver, Houston, Minneapolis, New York City, Philadelphia, Phoenix, Spokane, and St. Louis. Modeling was performed for 1990, 1996, 2007, and 2020. The forecast years include four control scenarios that were defined in consultation with EPA:

0. Baseline fuels and emission rates, assuming the implementation of a National Low-Emission Vehicle (NLEV) program;

1. Baseline emission factors with an assumed national gasoline regulation limiting sulfur levels to 40 ppm;

2. Scenario 1 with more stringent tailpipe hydrocarbon emission standards for light-duty cars and trucks (i.e., reflecting possible Tier 2 standards); and

3. Scenario 2 with an assumed increase in light-duty Diesel truck implementation equivalent to 50% of total light-duty truck sales beginning in model year 2004.

The methodology used to determine motor vehicle toxics emission rates, exposure, and cancer risk consisted of the following steps:

1. On-road motor vehicle toxic pollutant emission factors (in mg/mi) were generated using a modified version of the MOBILE5b emission factors model. That model, known as T2ATTOX, has been revised to allow the user more flexibility to model the impacts of off-cycle operation and fuel sulfur effects. In addition, that model allows the user to input toxics fractions (by model year and technology) that are applied to total organic gas (TOG) emission rates calculated by the model. This step involved the development of TOG base emission rate equations (BERs) as well as toxics fractions.* The toxic pollutants evaluated in this study included benzene; formaldehyde; acetaldehyde; 1,3-butadiene; MTBE; and Diesel particulate (which was estimated with the PART5 model). Toxic pollutant emission rates were calculated for each of the urban areas, calendar years (separate estimates for quarters 1 to 4), and control scenarios included in this study.

2. On-road motor vehicle carbon monoxide (CO) g/mi emission factors were developed for each of the urban areas included in the study using the Tier 2 Analysis Tool (T2AT). These calculations were performed for calendar year 1990 to be consistent with the CO exposure estimates described in Step 3 below.

3. CO exposure estimates (in $\mu g/m^3$) were calculated previously for the nine urban areas included in this study for calendar year 1990. Using the CO emission factors developed in Step 2 above, ratios of CO exposure (adjusted to reflect only the on-road motor vehicle contribution to the inventory in each urban area) to the CO emission factor for 1990 were developed. These ratios were prepared for the entire population, children under 18 years of age, and outdoor workers (the highest exposed demographic group) for quarters 1 to 4.

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* As described in Section 4 of this report, the final methodology developed for this project uses a slightly different approach for estimating exhaust toxics emission rates. (See the discussion of toxic-TOG curves in the text.)

4. Using the toxic pollutant emission rates and the CO ratios described above, estimates of toxic exposure were developed for each urban area, calendar year (by quarter), and control scenario investigated in this study. These estimates were calculated according to the following formula:

$$TOX_{Exposure(\mu g/m3)} = [CO_{Exposure(\mu g/m3)}/CO_{EF(g/mi)}]_{1990} \times TOX_{EF(g/mi)}$$

   where TOX reflects one of the six toxic pollutants considered in this study. Because some of the toxic pollutants evaluated in this study (e.g., 1,3-butadiene) have a different photochemical reactivity than CO, the exposure concentrations were adjusted to account for atmospheric transformation. In addition, because the CO ratios are based on the 1990 calendar year, an adjustment was made to account for the increase in VMT relative to 1990. These adjustments were developed in consultation with EPA.

5. Using the toxic pollutant exposure concentrations generated in Step 4, a methodology to estimate cancer risk was developed that applies cancer potency estimates (i.e., unit risk factors) for each toxic to the exposure estimates. Because cancer potency estimates were not finalized for inclusion in this work assignment, the model developed to compile the emissions and exposure data was structured to allow the user to input alternative potency estimates. Based on these inputs, the model calculates cancer risk for the entire population, the highest exposed demographic group (i.e., outdoor workers), and children 0 - 17 years of age. Total cancer cases for the entire population of each modeled urban area can be estimated, and the model includes an algorithm to estimate nationwide motor vehicle toxics exposure, cancer risk, and cancer cases.

This project was conducted by Sierra Research, Radian International, and Energy & Environmental Analysis. Sierra served in an oversight capacity and had primary responsibility for generating on-cycle toxics fractions, TOG base emission rate equations, and the CO emissions estimates. In addition, Sierra was responsible for generating exposure estimates and developing the model to estimate cancer risk. Radian was responsible for constructing T2ATTOX and PART5 input files, modifying the model to incorporate the methodologies developed during the course of this project, and performing the model runs. Finally, EEA performed an analysis of off-cycle speciated data to generate off-cycle toxics fractions.

Organization of the Report

This report is bound as two separate volumes. This volume (Volume I) contains a description of the study, the methodologies used to generate toxic emission rate and exposure estimates, and a summary of the results. Volume II contains detailed toxic emission rate and exposure estimates calculated for each of the study areas, years, control scenarios, seasons, and demographic groups evaluated in this effort.

Immediately following this introduction, Volume I continues with Section 3, which describes the modifications to the MOBILE5b modeling methodology for calculating TOG and CO emissions to account for a number of planned revisions for MOBILE6. This includes revised base emission rate equations, inclusion of off-cycle emissions impacts, revised fuel sulfur and oxygenate effects, and revised fleet characteristics. Section 4 presents the modeling methodology used to estimate motor vehicle air toxics emission rates. Section 5 details the specific MOBILE inputs used for the emissions modeling performed in this study, while Section 6 summarizes the results of the toxics emissions modeling. Section 7 explains how the emissions data were combined with 1990 CO exposure data to generate toxics exposure estimates for this study. The results of that modeling are also briefly discussed in that section. Finally, Section 8 presents a summary of risk assessment, and describes how the exposure model developed for this study was structured to allow the user to input alternative unit risk factors to calculate individual cancer risk and estimated cancer cases. A listing of the references cited in this report is contained in Section 9.

Volume II of this study consists of only of tables that summarize the results of the evaluation. The two primary sections of that volume are:

- Modeled Urban Area Toxics Emission Estimates; and

- Modeled Urban Area Toxics Exposure Estimates.

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3. TOG AND CO MODELING METHODOLOGY

As outlined in the previous section of this report, estimates of total organic gas (TOG) and carbon monoxide (CO) emission rates are needed for this study. As such, EPA's MOBILE model served as the basis of those estimates. The latest "official" version of EPA's on-road motor vehicle emission factors model is MOBILE5b, which was based on the MOBILE5a model. Although MOBILE5b was released in October 1996, the changes made to the model were minimal relative to MOBILE5a, consisting primarily of (1) revisions to account for the effect of regulations that had been finalized after the release of MOBILE5a, and (2) revisions to inspection and maintenance (I/M) program inputs to reflect program designs being pursued by states that were not included in the MOBILE5a model. The most substantive change to CO modeling between MOBILE5a and MOBILE5b was a result of including the impacts of the gasoline detergent additive regulation in the MOBILE5b model.

Most of the algorithms included in MOBILE5b are based on data and analyses performed nearly six years ago. (MOBILE5 was released in December 1992. That model was updated and released as MOBILE5a in March 1993 to correct errors found in the original release of the model.) Since that time, a significant amount of data has been collected on in-use emissions performance, vehicle operational characteristics, and the impact of fuel parameters on emissions. Because of that, EPA is now in the process of updating MOBILE5b to reflect the latest knowledge on vehicle emissions. In fact, a modified version of the model was developed to estimate the emissions impacts of possible Tier 2 controls. As discussed in the documentation prepared for that model,[3] which is termed the Tier 2 Analysis Tool (T2AT), the modified MOBILE5b model was developed as a "surrogate for MOBILE6," addressing four primary areas of development: (1) basic emission rates, (2) off-cycle effects, (3) fuel effects (primarily sulfur), and (4) fleet characteristics.[*]

To be consistent with the modeling performed for the Tier 2 Study, the analysis of air toxics performed under this work assignment made use of many revisions expected to be incorporated into MOBILE6. Although a number of the factors have been revised by EPA since the release of the T2AT results, the same elements of the model were addressed in the emissions estimates performed for this study. These include the following:

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[*] EPA has also developed a toxics version of T2AT, termed T2ATTOX. The T2ATTOX model was the basis of the emissions estimates prepared in this study.

- Base Emission Rates - The base emission rates (BERs) used in this study were updated by EPA based on more recent test data. The revised BERs reflect much lower deterioration rates than the current factors in MOBILE5b. This shift was directed at mid- to late-1980 model year vehicles and later. Thus, the net impact of this change is to lower fleet average in-use emission rates for future calendar years (i.e., the impact of fleet turnover is greater than that predicted by MOBILE5b).

- Off-Cycle Effects - Concern about inconsistencies between ambient measurements and inventory estimates led to a closer evaluation of the basis of emission factor estimates in the late 1980s. As a result, the 1990 Clean Air Act Amendments directed EPA to assess the magnitude of “off-cycle” emissions and develop regulations for their control. During the early 1990s, a significant effort to better define in-use vehicle operation was undertaken by EPA and CARB. The result of that effort was the development of driving cycles more representative of true vehicle operation (i.e., higher speed and acceleration). In addition, Supplemental Federal Test Procedure (SFTP) regulations were adopted that will control off-cycle emissions starting with the 2000 model year (2001 for NLEVs). The net result of adding off-cycle emissions impacts is to increase emissions for pre-SFTP vehicles, which are then decreased in future years as SFTP controls are implemented and the fleet turns over.

- Revised Fuel Effects - The impact of both gasoline sulfur and oxygen levels will be revised in MOBILE6. The impact of gasoline sulfur levels has been found to be more pronounced for low-emission vehicles than for older technologies (at least on a percentage basis); thus, this analysis addresses only the impacts of fuel sulfur on LEV-category vehicles. For oxygenated fuels, draft correction factors have been proposed by EPA that indicate the oxygenated fuel CO benefits for late-model vehicles are much lower than those predicted by MOBILE5b. These revised factors were incorporated into the CO estimates prepared for this study.

- Revised Fleet Characteristics - Because of the high sales fraction of light-duty trucks relative to passenger cars in the last several years, estimates of the car versus truck VMT split are being revised for MOBILE6. Current indications are that there will be a large shift to light trucks with MOBILE6, with the trend continuing beyond 2010. Because of the higher per-mile emission rates of light trucks relative to passenger cars, this shift will result in an increase in fleet-average emissions in the future. In addition to the car/truck VMT fractions, vehicle age distributions are being revised for MOBILE6 that will likely result in an older vehicle fleet than currently predicted by MOBILE5b. However, in the short-term, continued use of local data is preferable. These modifications were also incorporated into the emissions estimates prepared for this study.

Described below are the specific changes made to the MOBILE inputs to incorporate the revisions outlined above. Note that the model used in this analysis was a toxics version of T2AT developed by EPA called T2ATTOX. That model was provided to us by EPA and contained modifications to allow the estimation of motor vehicle air toxics emission rates. Although that model was ultimately revised by the study team to streamline calculations and modify several specific aspects of the methodology, it served as the basis for the emissions estimates prepared for this study.

TOG Emissions

The first step in estimating toxic emission rates from on-road motor vehicles was to make revisions to the MOBILE5b TOG inputs and calculation methodology to better reflect the anticipated structure of MOBILE6. Properly characterizing TOG emissions is important because both exhaust and evaporative TOG emission rates serve as the basis of the toxics emissions estimates, i.e., toxic emissions are generally estimated by assuming a certain fraction of TOG consists of the compound of interest. For example, benzene typically comprises 3% to 4% of light-duty gasoline vehicle exhaust TOG emissions. Thus, a vehicle with a TOG emission rate of 1.0 gram per mile (g/mi) would be expected to emit between 0.03 and 0.04 g/mi benzene.[*]

As outlined above, EPA is currently in the process of revising the MOBILE model to better reflect current knowledge and data on in-use emissions. Although none of the revisions planned for MOBILE6 have been finalized, it is possible to make educated assumptions regarding the nature of those revisions. This was done during the development of the emissions estimates for the Tier 2 Study, and EPA continues to refine its estimates of in-use emissions. For this study, EPA provided inputs or revisions to the following model parameters related to TOG emissions estimates:

- Base emission rate equations;
- Off-cycle corrections;
- Fuel sulfur impacts for low-emission vehicles; and
- Fleet characteristics (e.g., registration distributions).

A review of these parameters and the approach used to incorporate them into the model is discussed below.

Base Emission Rate Equations - EPA provided the base emission rates to be used in this study in terms of non-methane hydrocarbons (NMHC), which were subsequently converted to a TOG basis for input to the MOBILE model. Because toxics emissions were estimated out to 2020 in this effort, future-year emission rates were an important element of the analysis. For this evaluation, it was assumed that a national low-emission vehicle (NLEV) program would be implemented beginning in model year 2000 for areas

[*] This value could actually be more or less, depending on the benzene and aromatic content of the gasoline.

in the Ozone Transport Region (OTR) and in model year 2001 for non-OTR regions. Four sets of baseline BERs were provided by EPA, representing various levels of control:

- Non-I/M, Non-OTR NLEV implementation schedule;
- I/M, Non-OTR NLEV implementation schedule;
- Non-I/M, OTR NLEV implementation schedule; and
- I/M, OTR NLEV implementation schedule.

In addition to the above, a separate set of BERs was provided to reflect possible Tier 2 emission standards. These factors were effective with the 2004 model year.

A summary of the revised NMHC BERs for light-duty gasoline vehicles (LDGVs), light-duty gasoline trucks under 6,000 lbs. gross vehicle weight rating (LDGT1s), and light-duty gasoline trucks over 6,000 lbs. gross vehicle weight rating (LDGT2s) is contained in Table 3-1. The BERs in that table reflect the I/M, Non-OTR emission rates. In addition, the 2004 and later model year BERs reflect vehicles certified to proposed Tier 2 standards.

Table 3-1

Table 3-1
Revised FTP-Based NMHC BERs Used in Emissions Analysis
I/M[a], Non-OTR NLEV Implementation

Vehicle Class	Model Year	ZM (g/mi)	DR1 (g/mi/10K)	DR2 (g/mi/10K)	Flex Point (10,000 mi)
LDGV	1981-82	0.308	0.115	0.162	1.528
	1983-85	0.197	0.039	0.107	2.223
	1986-89	0.240	0.046		
	1990-94	0.167	0.016	0.034	2.126
	1995-2000	0.145	0.010	0.019	8.903
	2001-03	0.059	0.006	0.010	7.872
	2004+	0.036	0.005	0.009	8.103
LDGT1	1984-89	0.398	0.018	0.088	4.409
	1990-94	0.266	0.015	0.039	2.133
	1995-2000	0.179	0.010	0.021	9.063
	2001-03	0.076	0.006	0.011	8.287
	2004+	0.036	0.005	0.009	8.103
LDGT2	1984-89	0.398	0.018	0.088	4.409
	1990-96	0.266	0.015	0.039	2.133
	1997-2003	0.218	0.010	0.025	9.254
	2004+	0.036	0.005	0.009	8.103

Several items are worth noting with respect to the revised BERs contained in Table 3-1. First, only 1981 and later BERs are included for LDGVs, and only 1984 and later are included for LDGTs. That is because the earlier model year BERs did not change relative to MOBILE5b. Second, although these are I/M-based emission rates, the impact of I/M is accounted for only in the 1995 and later model year LDGV/LDGT1 categories and the 1997 and later LDGT2s. That is because the earlier model year vehicles are corrected for I/M effects with alternative credit files that were developed by EPA. Finally, significant reductions in the base emission rate equations are observed in 2001 as a result of the NLEV program, and then again in 2004 as a result of potential Tier 2 controls. Also of note is that although the LDGT2 category is not part of the NLEV program, it was modeled in this effort as being controlled by potential Tier 2 regulations. This becomes important in the future as more trucks are certified in the heavier weight classes.

To put the revised BERs in perspective, they have been plotted against the MOBILE5b base emission rates in Figure 3-1. The two top lines in that figure represent non-I/M hydrocarbon emissions for Tier 0 and Tier 1 vehicles modeled by MOBILE5b. The four bottom lines in the figure reflect the revised BERs used in this analysis. The Tier 0 and Tier 1 rates do not include the effects of I/M, so they are directly comparable to the MOBILE5b factors.[*] The NLEV and Tier 2 rates do include I/M. As seen in the figure, the revised BERs are significantly lower than the MOBILE5b estimates.

In addition to making revisions to the light-duty vehicle NMHC emission rates,[**] BERs for heavy-duty gasoline vehicles (HDGVs) and heavy-duty Diesel vehicles (HDDVs) were also revised. Again, the modified rates were provided by EPA and are summarized in Table 3-2.

A final adjustment that was made to the BER equations before formatting them for use in the T2ATTOX model was to adjust the NMHC values to a TOG basis. (For the calculation of air toxics, the T2ATTOX model requires alternative BERs to be input in terms of TOG.) These adjustments were provided by EPA and are a function of vehicle class and technology. For example, the following TOG/NMHC correction factors were used for light-duty gasoline cars and trucks:

- Non-catalyst - 1.0988
- Oxidation catalyst - 1.1725
- Three-way catalyst - 1.1687
- Three-way + oxidation catalyst - 1.3829

[*] Note that the MOBILE5b rates are reported in terms of total HC (which included methane), while the revised rates are in terms of NMHC. Correcting the MOBILE5b results to an NMHC basis would lower those rates, but only slightly.

[**] At the request of EPA, light-duty Diesel cars and trucks were assigned the same NMHC emission rate as gasoline vehicles for Tier 1 vehicles, Tier 2 vehicles, and NLEVs.

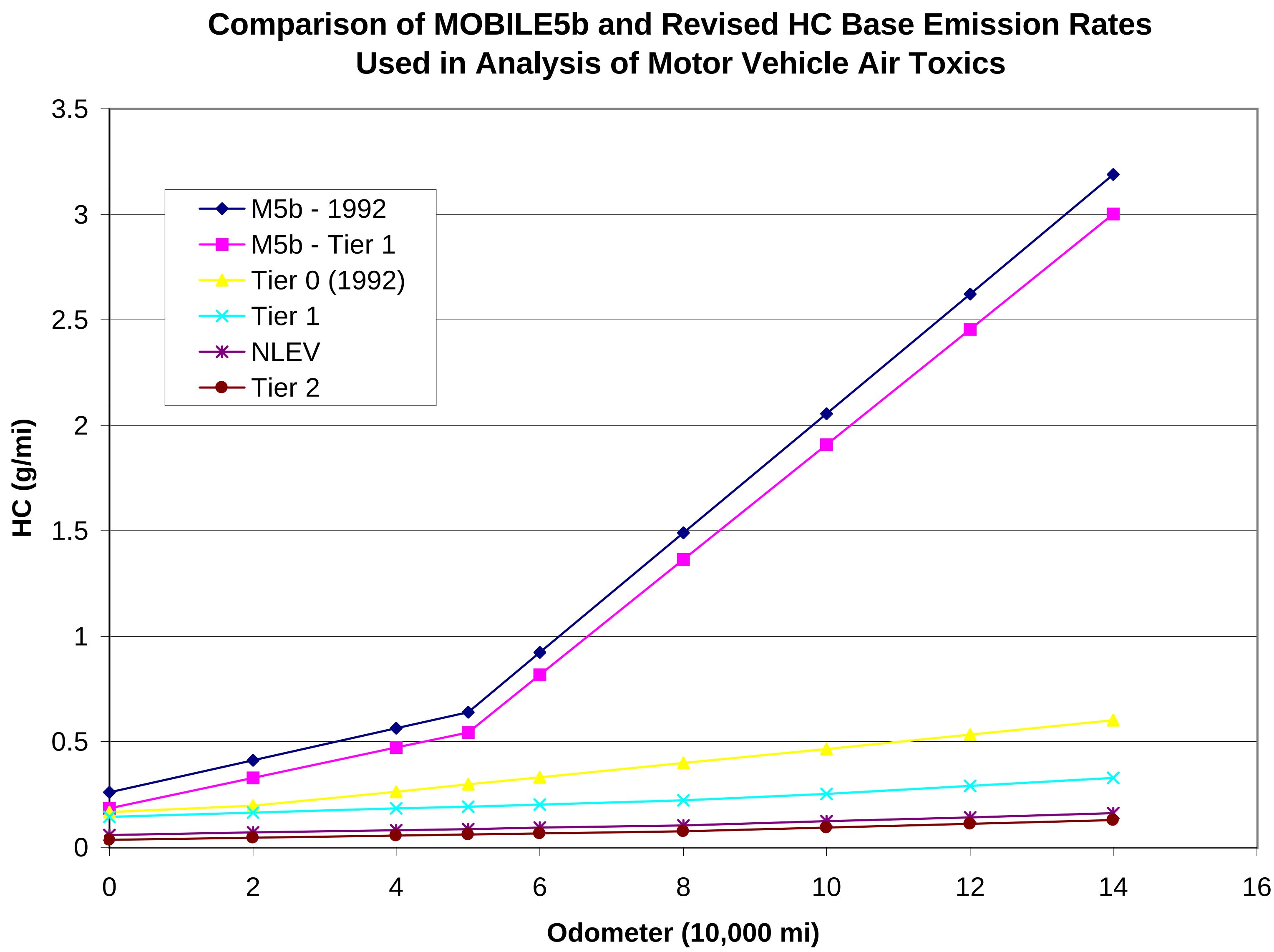
Comparison of MOBILE5b and Revised HC Base Emission Rates
Used in Analysis of Motor Vehicle Air Toxics
HC (g/mi)
Odometer (10,000 mi)
M5b - 1992
M5b - Tier 1
Tier 0 (1992)
Tier 1
NLEV
Tier 2
0
0.5
1
1.5
2
2.5
3
3.5
0
2
4
6
8
10
12
14
16

Figure 3-1

Table 3-2
Revised NMHC BERs for HDGV and HDDV Vehicle Classes

Vehicle Class	Model Year	ZM (g/bhp-hr)	DR (g/bhp-hr/10,000 mi)
HDGV	1994-2003	0.364	0.023
	2004+	0.277	0.018
HDDV	1994-2003	0.283	0.0
	2004+	0.257	0.0

These factors were used to generate model-year specific TOG/NMHC ratios by weighting each model year by the fraction of each technology in the fleet. Those calculations were performed by EPA and the results were submitted to Sierra in spreadsheet form. A summary of the TOG/NMHC ratios used in this study, by model year and vehicle class, is contained in Appendix A. In addition, the resulting BERs, in the format used by the T2ATTOX model, are also summarized in Appendix A.

Note that the emission factors provided by EPA were based on low altitude. Because Denver was one of the urban areas modeled in this study, adjustment for high-altitude operation had to be made. This was accomplished by determining the ratio of $(BER_{High-Alt}/BER_{Low-Alt})_{Mobile5b}$ and applying that ratio to the revised low-altitude base emission rates. Note that this adjustment was applied only to the zero-mile level, since the low-altitude and high-altitude deterioration rates in MOBILE5b are the same.

<u>Off-Cycle Effects</u> - Off-cycle corrections were also provided by EPA for use in this analysis. Those corrections, consisting of separate adjustments for aggressive driving behavior and air conditioning (A/C) usage, are different for I/M versus non-I/M areas. (This is based on the fact that normal-emitting vehicles have a different off-cycle response compared to high-emitting vehicles. Since I/M influences the fraction of normals and highs in the fleet, there is a different adjustment for each area.) For 1981 and later model year vehicles, the correction factors provided by EPA were formatted as multiplicative adjustments. For pre-1981 model year vehicles, however, three different sets of emission factors (zero-mile levels and deterioration rates) were provided: (1) uncorrected; (2) corrected for aggressive driving; and (3) corrected for aggressive driving and air conditioning usage. Separate I/M and non-I/M factors were not provided for the pre-1981 model year vehicles.

To simplify the modeling, the pre-1981 emission factors were combined with the MOBILE5b-calculated mileage versus age estimates for the 1990 and 1996 calendar years. (For the 2007 and 2020 analyses, pre-1981 model year vehicles are no longer in the fleet; thus, there is no need to calculate pre-1981 off-cycle corrections for those calendar years.) The resulting emission rates were then used to calculate multiplicative correction factors on the same basis as the 1981 and later model year factors provided by EPA. For example, in 1996, a 1980 model year LDGV is projected to have accumulated 155,210 miles. Thus, using the BER equations provided by EPA (reported in terms of a zero-mile level and a deterioration rate), emission rates for the three cases outlined above are:

	ZM		DR		Miles		Emissions
(1) Uncorrected:	0.313	+	0.178	*	15.521	=	3.076 g/mi
(2) Agg Driving:	0.384	+	0.216	*	15.521	=	3.737 g/mi
(3) Total Off-Cycle:	0.399	+	0.224	*	15.521	=	3.876 g/mi

The 1981 and later adjustment factors were based on a separate aggressive driving factor and a separate A/C factor that, when multiplied together, give the total off-cycle factor. Thus, the aggressive driving element in the example above is calculated as:

$AGG_{1980MY} = 3.737 / 3.076 = 1.215$

and the overall off-cycle factor is:

$OCCF_{1980MY} = 3.876 / 3.076 = 1.260$

The A/C factor is then calculated as follows:

$OCCF_{1980MY} = AGG_{1980MY} * A/C_{1980MY}$

$A/C_{1980MY} = OCCF_{1980MY} / AGG_{1980MY}$

$A/C_{1980MY} = 1.260 / 1.215 = 1.037$

The results from this evaluation are summarized in Table 3-3 for pre-1981 model year vehicles, along with the factors for 1981 and later model year vehicles (which were given directly in terms of multiplicative factors). Note that the aggressive driving factor calculated above for the 1980 model year is slightly different than that shown in the table because of rounding differences. The off-cycle TOG correction factors shown in Table 3-3 are for the LDGV vehicle class for 2007 and later calendar years. (The 2007 calendar year is shown here so that a complete range of model years can be compared – the 1996 evaluation year captures pre-1981 factors.) A complete set of off-cycle factors used in this analysis is contained in Appendix A.*

Several points can be made with respect to the TOG off-cycle corrections contained in Table 3-3. First, the off-cycle effects are greatest for 1981 to 2000 model years. Beyond 2000, the impact of the SFTP regulations take effect and the off-cycle impact is substantially reduced. Second, the difference between the I/M and non-I/M rates is very slight. Finally, the impact of air conditioning is very small, with a maximum of a 4% increase with the 1981 to 1994 model year group.

The aggressive driving element of the off-cycle correction factors was applied to the FTP-based TOG emission factor for all seasons, while the A/C adjustment was applied only to the spring and summer runs. As described below, a more sophisticated methodology was used to evaluate the impact of A/C usage on CO emissions. However, because the impact of A/C usage on TOG emissions is so small, a more simplistic approach was used. Finally, the multiplicative off-cycle factors in Table 3-3 were applied to the temperature-corrected FTP-based emission rates. Although some type of correction for temperature is probably warranted, there are no data with which to make such an adjustment. Thus, the aggressive driving factor likely results in a slight over-estimate of TOG emissions at low temperature.

* Note that the off-cycle files in Appendix A contain toxics multipliers that are used to account for the difference in toxics fractions between FTP operation and in-use operation. These multipliers are described in the next section of the report.

Table 3-3
TOG Off-Cycle Correction Factors
2007 and Later Calendar Years[a]

Model Year	Non-I/M Factors		I/M Factors	
	Agg Drv	A/C	Agg Drv	A/C
1965-1967	1.079	1.016	1.079	1.016
1968-1969	1.091	1.018	1.091	1.018
1970-1971	1.083	1.016	1.083	1.016
1972	1.130	1.025	1.130	1.025
1973	1.129	1.024	1.129	1.024
1974	1.128	1.024	1.128	1.024
1975	1.140	1.026	1.140	1.026
1976-1979	1.139	1.026	1.139	1.026
1980	1.210	1.037	1.210	1.037
1981-1994	1.228	1.040	1.230	1.040
1995-2000	1.287	1.010	1.290	1.010
2001	1.218	1.003	1.220	1.003
2002	1.149	0.995	1.150	0.995
2003	1.051	0.985	1.052	0.985
2004	1.010	0.980	1.010	0.980

[a] The pre-1981 model year factors reflect those used in a 1996 calendar year run.

Fuel Sulfur Impacts - Data recently collected by the Coordinating Research Council (CRC) and the auto industry have indicated that the impact of gasoline sulfur levels is more pronounced for low-emission vehicles than for older technologies (at least on a percentage basis). Because of this effect, EPA included sulfur adjustments in the emissions estimates prepared for the Tier 2 study. Such an adjustment was necessary because LEVs are expected to be certified with low-sulfur fuel (approximately 40 ppm S), while in-use fuel (in 1990) has been estimated to have a fuel sulfur level of 339 ppm. Thus, the LEV-category emission factors in this study were corrected from a 40 ppm S basis to a 339 ppm S basis. This was accomplished by using correlation equations provided by EPA. This resulted in a multiplicative adjustment of 1.44 for LDGVs and a multiplicative adjustment of 1.30 for LDGT1s. Because the MOBILE5b model includes an in-use fuel correction (part of which includes an adjustment for the difference in sulfur levels between certification fuel and in-use fuel), the factors above had to be further revised before use in the model so that the sulfur effect was not double counted. This was accomplished using the same approach as that outlined in the documentation prepared for the Tier 2 Study.[3] The final factors used in this study were therefore 1.36 for LDGVs and 1.23 for LDGT1s. These factors are included in the TOG base emission rate equations presented in Appendix A.

Fleet Characteristics - Two primary revisions to the modeling conducted in this study were made to account for more recent information on the fleet make-up. These included modifications to the LDGV, LDGT1, and LDGT2 registration distributions (i.e., the fraction of vehicles making up the fleet by vehicle age) and modifications to the VMT mix used to compile vehicle-class-specific emission rates into an overall fleet average. The registration distributions were modified to reflect the fact that vehicles are remaining in the fleet for a longer period of time. This effect was incorporated into the 2007 and 2020 model runs. (The locality-specific registration fractions were used in the 1990 and 1996 calendar year analyses.) The VMT mix was revised to account for the large increase in light-duty truck sales (e.g., minivans and sport-utility vehicles) over the last several years. Revised registration and VMT mix inputs were provided by EPA and are consistent with the values used in the Tier 2 Study. (More detail on the specific values used in this study is given in a later section of the report.)

CO Emissions

As outlined above, the TOG emissions estimates formed the basis of the toxics emissions estimates prepared for this study. As such, TOG emissions were calculated for the four calendar years evaluated in this work (i.e., 1990, 1996, 2007, and 2020). On the other hand, the CO emissions estimates were needed only for the 1990 calendar year. That is because they were used only to calculate the $[CO_{Exposure(\mu g/m3)} / CO_{EF(g/mi)}]_{1990}$ ratios. Those ratios were then combined with the toxics estimates to generate toxic exposure estimates for each scenario.

As with the TOG emissions estimates, a number of changes related to CO were made to the MOBILE5b model to implement revisions planned for MOBILE6. These include:

- Revised base emission rate equations;
- Application of off-cycle correction factors; and
- Revised oxygenated fuels effects.

A discussion of how these revisions were implemented for this study is included below.

Base Emission Rate Equations - The base emission rate equations supplied for this element of the study were also developed by EPA. Revised emission factors were provided for 1981 through 1990 model year LDGVs, and for 1984 through 1990 model year LDGT1s and LDGT2s. (Although the file containing the BERs included pre-1981 model year vehicles, those BERs are the same as the existing MOBILE5b factors.) A review of the BERs indicates that the revised factors include lower deterioration rates than the baseline MOBILE5b factors, similar to the TOG factors. A summary of the revised BERs is provided in Table 3-4, and the BER inputs used in the modeling are contained in Appendix A.

Because revised factors were supplied only for low-altitude areas, a correction for high altitude was needed for the Denver runs. This was accomplished by determining the ratio of $(BER_{High\text{-}Alt}/BER_{Low\text{-}Alt})_{Mobile5b}$ and applying that ratio to the revised low-altitude base emission rates. Note that this adjustment was applied only to the zero-mile level, since the low-altitude and high-altitude deterioration rates in MOBILE5b are the same.

The BERs contained in Table 3-4 were used in conjunction with the T2ATTOX model to generate CO emissions estimates for this study. That model was used because it is capable of accepting more detailed sets of alternative BERs than the MOBILE5b model (e.g., variable flex points). Although T2AT could have been used for this purpose, the non-toxics portion of the T2ATTOX code is no different when that model is used to generate HC, CO, and NOx emissions estimates, and it was used in this case because the code was immediately available for the off-cycle and oxygenated fuels revisions described below.

Table 3-4
Revised FTP-Based CO BERs Used in Emissions Analysis

Vehicle Class	Model Year	ZM (g/mi)	DR1 (g/mi/10K)	DR2 (g/mi/10K)	Flex Point (10,000 mi)
LDGV	1981 - 82	4.301	2.441	3.037	1.50
	1983 - 85	2.813	0.191	1.650	2.16
	1986 - 89	2.795	0.696		
	1990	2.188	0.076	0.556	1.85
LDGT1	1984 - 89	6.045	0.496	1.094	5.34
	1990	5.382	0.245	0.717	5.37
LDGT2	1984 - 89	6.045	0.496	1.094	5.34
	1990	5.382	0.245	0.717	5.37

Off-Cycle Corrections - CO off-cycle correction factors were also provided by EPA for use in this analysis. Those corrections were provided in the same format as the TOG factors described above, and the same processing of those results occurred for use in the T2ATTOX model (i.e., the pre-1981 factors were converted to multiplicative adjustments). A summary of the CO off-cycle factors used in this analysis is contained in Table 3-5 for LDGVs, and the complete set of factors is contained in Appendix A.

Of note in Table 3-5 is that the off-cycle correction factors are much larger for CO than for TOG, particularly the A/C correction (which was almost non-existent in the TOG analysis). When modeling the impacts of aggressive driving CO effects, there is concern that at low temperature (which causes greatly elevated CO emissions) a multiplicative adjustment may overstate the magnitude of the off-cycle increase. Thus, for this study, the aggressive driving element of off-cycle effects were incorporated by first determining a CO "offset" at 75°F, adjusting that estimate for fuels effects (i.e., in-use fuel and oxygenates), and then adding it to the temperature-corrected CO value estimated by the model. A similar approach was taken to incorporate the A/C effect, but this was only done when the ambient temperature was over 69°F as described below. These adjustments were performed within the "BEF" subroutine in T2ATTOX.

Table 3-5
LDGV CO Off-Cycle Correction Factors

Model Year	Non-I/M Factors		I/M Factors	
	Agg Drv	A/C	Agg Drv	A/C
1965 - 66	1.328	1.217	1.328	1.217
1967	1.324	1.215	1.324	1.215
1968	1.370	1.237	1.370	1.237
1969	1.365	1.235	1.365	1.235
1970	1.375	1.240	1.375	1.240
1971	1.371	1.238	1.371	1.238
1972	1.432	1.265	1.432	1.265
1973	1.426	1.263	1.426	1.263
1974	1.419	1.260	1.419	1.260
1975	1.574	1.321	1.574	1.321
1976	1.568	1.319	1.568	1.319
1977	1.560	1.316	1.560	1.316
1978	1.552	1.313	1.552	1.313
1979	1.543	1.310	1.543	1.310
1980	1.861	1.407	1.861	1.407
1981 - 91	1.611	1.326	1.630	1.340

The aggressive driving component was calculated for all model runs, while the A/C adjustment was applied only during periods of higher temperature (i.e., above 69°F). Further, between 69° and 85°F, the A/C adjustment was interpolated between 1.0 and the factor shown in Table 3-5. The 85°F point was chosen because it represents the temperature corresponding to a 52% compressor-on fraction,[4] which was the basis of the estimates given in Table 3-5. The factors were linearly scaled between 85° and 108°F, with the upper end of that range representing a 100% compressor-on fraction. Finally, the model-year-specific factors given in that table were adjusted for the fraction of vehicles assumed to be equipped with functioning air conditioning systems. These estimates were based on data contained in EPA's draft air conditioning activity effects recommended for MOBILE6[4] and are summarized in Appendix A.

Oxygenated Fuels Effects - The impacts of oxygenated fuels on CO emissions modeled in this effort were based on estimates prepared by Sierra under contract to API.[5] Sierra worked closely with EPA staff during the development of those estimates, and, in fact, EPA has recommended that the results of that study be used in the MOBILE6 model[6] to estimate the emissions impacts of oxygenated fuels on pre-1994 model year vehicles. Because the current analysis is aimed at the 1990 calendar year, estimates for Tier 1 and more advanced technologies were not needed. In addition, because the analysis referenced above only considered 1981 and later model year vehicles, the CO oxygenated fuel effects were revised in this analysis only for 1981 to 1990 model year vehicles; existing MOBILE5 oxygenated fuels impacts were retained for pre-1981 model year vehicles as well as for heavy-duty gasoline vehicles.

The oxygenated fuels impacts used in this analysis are summarized in Table 3-6. As observed in that table, the fuel oxygen impact is a function of emitter category and technology, i.e., vehicles equipped with adaptive learning (ADL) computer logic are less sensitive to oxygen in the fuel than are older technology vehicles. However, one shortcoming of this approach is that the fraction of the fleet equipped with ADL systems has not been estimated by model year. For this analysis, we needed only the fraction of vehicles equipped with ADL systems for 1986 and later model years (pre-1986 model year vehicles were analyzed separately, without regards to ADL capability).

Table 3-6
Recommended CO Effects From the Use of Oxygenated Fuels for Matched RVP Blends at 75°F

Emitter Category	Technology	CO Impact Per Wt% Oxygen	Typical MTBE Blend (2.7 wt% O)	Typical Ethanol Blend (3.5 wt% O)
Normal	1988+ TWC/ADL	-3.1% (n=133)[a]	-8.4%	-10.9%
	1986-87 TWC/ADL	-4.8% (n=104)	-13.0%	-16.8%
	1986+ TWC/No ADL	-5.7% (n=151)	-15.4%	-20.0%
	1981-85 TWC/CL	-4.0% (n=73)	-10.8%	-14.0%
	OX/OL[b]	-9.4%	-25.4%	-32.9%
	Non-Catalyst[b]	-6.6%	-17.8%	-23.1%
High	1981+ TWC/CL	-5.3% (n=134)[a]	-14.3%	-18.6%
	OX/OL[b]	-9.4%	-25.4%	-32.9%
	Non-Catalyst[b]	-6.6%	-17.8%	-23.1%

[a] Sample size shown in parentheses.

[b] Open-loop and non-catalyst factors are based on an EPA analysis used to support oxygenated fuel impacts in MOBILE4.1 and MOBILE5.[7]

Based roughly on the fraction of vehicles in the EPA emission factors database that were also included in the Complex model database (which, by design, had to be equipped with ADL), the following phase-in of ADL systems was assumed for this analysis:

- 1986 to 1987 - 50% equipped with ADL;
- 1988 to 1989 - 75% equipped with ADL; and

- 1990 to 1991 - 90% equipped with ADL.

Using the ADL technology weightings above (as well as the catalyst type technology weightings used elsewhere in this analysis), oxygenated fuel factors for normal and high emitting vehicles were generated for 1981 to 1991 model years, and the results are shown in Table 3-7 for LDGVs. Based on discussions with EPA, the light-duty truck categories were assumed to lag passenger cars in terms of ADL technology implementation by five years. Thus, the 1986+ TWC/No ADL factors from Table 3-6 were used to represent all 1986 to 1990 model year trucks. The final factors used in this analysis are summarized in Appendix A.

Table 3-7
Model-Year Specific CO Benefits from Oxygenated Fuel for LDGVs
(Reductions are in Terms of % per wt% Oxygen)

Model Year	Normals		Highs	
	% Red	g/mi	% Red	g/mi
1981	5.5	4.9	6.5	20.5
1982	5.8	4.9	6.6	20.5
1983	5.3	4.9	6.3	20.5
1984	4.3	4.9	5.5	20.5
1985	4.4	4.9	5.6	20.5
1986	5.4	3.2	5.4	20.5
1987	5.3	3.2	5.4	20.5
1988	3.8	3.0	5.3	20.5
1989	3.8	3.0	5.3	20.5
1990	3.4	2.8	5.3	20.5
1991	3.4	2.8	5.3	20.5

Because different oxygenated fuels impacts are applied to normal-emitting vehicles and to high-emitting vehicles, a method to estimate the fraction of normals and highs in the fleet (as a function of vehicle or mileage) was needed. This was accomplished by first determining the average CO emission level of the normal- and high-emitting vehicles used to generate the CO impacts listed in Table 3-6. These averages were used to compute the mean normal and high emission rate in the model-year-specific factors shown in Table 3-7.

From Table 3-7, the mean CO from a 1988 normal-emitting LDGV is 3.0 g/mi and the mean CO from a high-emitting vehicle is 20.5 g/mi. If the mean CO emission rate of a 1988 LDGV in calendar year 1990 is 7.0 g/mi, then the fraction of normal emitters in the fleet at that point (N) can be determined as follows:

$$7.0 \text{ g/mi} = 3.0*N + 20.5*(1-N)$$

Solving the above equation for N results in 77.1% of the fleet being normal emitters and 22.9% of the fleet being high emitters. The impact of oxygenated fuel (assuming 3.5% oxygen by weight) can then be estimated as follows (taking values from Table 3-7 for the 1988 model year):

Non-oxygen CO = 3.0*0.771 + 20.5*0.229 = 7.01 g/mi

Oxygen CO = 3.0*0.771*(1-0.038*3.5)
+ 20.5*0.229*(1-0.053*3.5) = 5.83 g/mi

Thus, an overall oxygenated fuel benefit of 16.8% (i.e., 1 - 5.83/7.01) is estimated for this case. This same general approach was used to determine the oxygenated fuel impacts for all 1981 and later model year cars and light trucks. This methodology was incorporated into the T2ATTOX model by making revisions to the “FUEL” subroutine.

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4. TOXICS EMISSIONS MODELING METHODOLOGY

Once the revisions to the methodology and inputs needed to estimate TOG emissions were finalized, it was necessary to develop an approach to generate air toxics estimates. As described below, the approach utilized for exhaust emissions makes use of "toxic-TOG" curve in which the FTP-based g/mi TOG emission rate was used to extract the corresponding mg/mi toxic emission rate. In this way, the differences in toxics fractions between normal- and high-emitting vehicles were accounted for in the calculations. For evaporative emissions, a simpler method was used in which the mass fraction of each toxic (as a fraction of TOG emissions) was applied to the evaporative emissions estimates calculated by the standard MOBILE5b routine contained within the T2ATTOX model. Finally, Diesel PM emissions were estimated directly from EPA's PART5 model. Each of these elements of the toxics modeling performed for this study is presented in this section of the report.

Exhaust Emissions

Previous EPA Estimates - During the development of the 1993 Motor Vehicle Related Air Toxics Study, EPA spent considerable effort developing estimates of on-road motor vehicle air toxics. At that time, the number of motor vehicle test programs that measured air toxics was limited, and because most of the available data were from low-mileage, well-maintained vehicles, EPA found it difficult to develop a direct gram per mile (or milligram per mile) toxic emission rate reflective of the in-use fleet. Instead, available emissions data were used to estimate air toxics emissions as a fraction of the total organic gases (TOG) emitted from the test vehicles. Those estimates were then applied to output from an emission factor model (MOBILE4.1 in the case of the EPA MVRATS) to estimate air toxics from the in-use fleet.

In developing emission estimates for motor vehicle air toxics, EPA found that the toxics fractions were a function of a vehicle's emission control system design and fuel type (i.e., gasoline versus Diesel). Thus, toxics fractions were developed separately for each of the following technologies:

- three-way catalyst (TW CAT),
- three-way plus oxidation catalyst (TW+OX CAT),
- oxidation catalyst (OX CAT),

- no catalyst (NO CAT),
- light-duty Diesel vehicle (LD Diesel), and
- heavy-duty Diesel vehicle (HD Diesel).

A summary of the toxics fractions for benzene, 1,3-butadiene, formaldehyde, and acetaldehyde from the 1993 MVRATS is contained in Table 4-1. Several items are worth noting with respect to this table. First, although the benzene fractions are reported as single values, EPA developed equations for the gasoline technologies that estimated the benzene fraction as a function of fuel benzene content and fuel aromatic content (i.e., as fuel benzene and aromatic content go up, so does the benzene fraction in the exhaust).[*] The benzene fractions shown in Table 4-1 are based on the fuel parameters specified in the Clean Air Act for baseline gasoline (i.e., RF-A in the Auto/Oil Air Quality Improvement Research Program). Second, although the 1,3-butadiene, formaldehyde, and acetaldehyde fractions are shown as single values, EPA found those to vary as a function of whether the gasoline contained oxygenate. (The values in the table assume no oxygenate.) For example, a fuel containing MTBE would result in higher formaldehyde fractions than shown in Table 4-1.

Table 4-1
Exhaust Toxics Fractions as a % of TOG Emissions
Used by EPA in the 1993 Motor Vehicle Related Air Toxics Study

Technology	Benzene[a]	1,3-Butadiene	Formaldehyde	Acetaldehyde
TW CAT	5.27	0.57	0.87	0.47
TW+OX CAT	2.87	0.44	1.37	0.45
OX CAT	4.05	0.44	1.39	0.44
NO CAT	4.05	0.98	2.69	0.62
LD Diesel	2.29	1.03	3.91	1.25
HD Diesel	1.06	1.58	2.80	0.75

[a] The benzene fractions for gasoline-fueled vehicles are based on 1990 industry-average gasoline, which contained an average of 1.53 vol% benzene and 32 vol% aromatics.

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[*] Note that oxygenate was determined not to have a significant direct impact on the percentage of benzene in exhaust, and it is not a parameter in the equations developed by EPA. However, to the extent that the addition of oxygenate reduces the concentration of benzene and aromatics through dilution effects, it indirectly affects the percentage of benzene in exhaust hydrocarbons.

Also of interest in Table 4-1 is the fact that benzene and 1,3-butadiene fractions are higher for more advanced emission control technology (i.e., the TW CAT technology). However, the lower overall TOG mass from those vehicles more than compensated for the increased toxics fractions, and a net reduction in toxics emissions resulted from newer technology vehicles in EPA's analysis.

Complex Model for Reformulated Gasoline - Following the release of the 1993 MVRATS, EPA finalized the reformulated gasoline (RFG) regulations. As part of those regulations, the Complex model[8] was developed that allows refiners to assess whether particular fuel formulations meet the RFG performance standards (i.e., percent reductions of VOC, NOx, and toxics). That model calculates the emissions impacts of alternative gasoline formulations relative to the baseline 1990 industry average fuel defined in the 1990 Clean Air Act Amendments. The fuel parameters included in the calculations are listed below.

- Oxygenate content (wt %) and type (i.e., MTBE, ethanol, ETBE, or TAME)
- Sulfur content (ppm)
- RVP (psi)
- E200 (%)
- E300 (%)
- Aromatics (vol %)
- Olefins (vol %)
- Benzene (vol %)

In addition to VOC and NOx, the Complex model estimates the impact of varying fuel formulation on benzene, acetaldehyde, formaldehyde, 1,3-butadiene, and polycyclic organic matter (POM) exhaust emissions. Because the Complex model was based on a much larger database than the toxic fractions used in the MVRATS, EPA has been criticized in the past for not using the Complex model results in that study. However, that criticism is not warranted, since the Complex model was not available at the time the emissions analysis was performed for the MVRATS. In addition, the Complex model has its own limitations. First, the database used to develop the Complex model included only 1986 to 1990 model year vehicles, so it cannot be used to predict toxic emission rates from older technology vehicles, and projecting results onto future technologies introduces uncertainty into the analysis. Second, only gasoline-fueled light-duty cars and trucks were included in the Complex model database, so it cannot be used to predict toxics emissions from Diesel vehicles, heavy-duty gasoline vehicles, or motorcycles.

The above limitations notwithstanding, the Complex model remains the most robust tool currently available with which to estimate toxics emissions from late-model vehicles, particularly when alternative fuel formulations are being investigated. For that reason, the Complex model was used in this study to generate toxics emissions estimates from light-duty vehicles equipped with three-way catalyst systems. For this analysis, EPA provided an "unconsolidated" version of the Complex model that generated separate emissions estimates as a function of technology, e.g., port fuel injection (PFI) was broken out separately from throttle body injection (TBI). In addition, results were reported separately for normal-emitting vehicles and for high-emitting vehicles. With this level of detail, it was possible to generate model-year-specific toxics fractions and emission rates by applying the appropriate technology sales mix to each model year and vehicle class. In addition, because the response to differing fuel formulations is often much different for high-emitting vehicles relative to normal-emitting vehicles, modeling those effects separately resulted in improved toxics emissions estimates.

A sample output from the unconsolidated Complex model is given in Figure 4-1. For that particular run, the fuel parameters for Chicago in the summer of 1990 were used. As outlined in the figure, the model first calculates a percentage change for exhaust VOC, exhaust benzene, acetaldehyde, formaldehyde, and 1,3-butadiene based on the difference in fuel parameters between the baseline gasoline (as defined in the Clean Air Act) and the target fuel. These percentage changes are then applied to baseline emission rates (in mg/mi) to arrive at the target fuel emission rate. For the winter runs, the baseline fuel specifications are slightly different. In addition, the winter runs held the RVP to 8.7 psi for both the baseline and target fuel because RVPs typical of wintertime fuels (e.g., on the order of 13.5 psi) are outside the range of the Complex model. Finally, because temperature corrections were applied within the modified MOBILE model developed for this study, the technology-group-specific baseline emission rates in the summer version of the Complex model were not modified to reflect winter temperatures.

As part of this study, MTBE emissions were also estimated. However, the standard version of the Complex model does not calculate MTBE emissions separately. Thus, EPA provided Sierra with an unpublished version of an MTBE model that is patterned after the Complex model.[9] It should be noted that the MTBE model contains a strong caveat that the regression analyses upon which the model was based have not been peer reviewed, and therefore the results are subject to some uncertainty.

<u>Treatment of Normal and High Emitters (“Toxic-TOG Curves”)</u> - An issue that received considerable discussion at the beginning of this project was how to implement an approach that treated normal and high emitters separately. The issue here is that normal emitters and high emitters may have different characteristics in terms of their response to fuel parameters (and corresponding toxics fractions) and therefore need to be treated separately. This becomes difficult when different I/M scenarios are considered that impact the distribution of normals and highs in the fleet. A methodology to account for normal and high emitters within the T2ATTOX code was suggested by EPA. A summary of this method is presented below, and the original write-up provided by EPA is included in Appendix B.

Although the approach suggested by EPA was presented in algebraic terms, it is useful to start with a simple example and work backward from there. Assume that the TOG emission rates, benzene emission rates, and benzene fractions for normal and high emitters corresponding to a baseline fuel and a target fuel are as listed in Table 4-2. Using the values presented in Table 4-2, if T2ATTOX calculated a fleet-average emission rate of 1.0 g/mi TOG for the baseline fuel, the fraction of normals and highs making up the 1.0 g/mi emission rate could be calculated as follows:

Figure 4-1

Unconsolidated Complex Model Run Based on Chicago 1990 Summertime Fuel Parameters

Fuel Prameters

	CAA Base	Target Fuel
OXYGEN (wt%)	0	0
SULFUR (ppm)	339	512
RVP (psi)	8.7	8.67
E200 (%)	41	47.2
E300 (%)	83	78.6
AROMATICS (vol%)	32	28.8
OLEFINS (vol%)	9.2	8.6
BENZENE (vol%)	1.53	1.35

Percent Change

	Exh VOC	Exh ben	Ace	Form	But
TG 1	8.91	0.21	12.32	6.97	11.95
TG 2	6.63	-6.16	12.32	6.97	2.57
TG 3	10.85	4.90	12.32	6.97	7.61
TG 4	19.67	-6.16	11.63	6.97	-4.38
TG 5	18.25	-12.66	12.32	6.97	2.57
TG 6	5.37	-6.16	12.32	6.97	11.18
TG 7	11.10	-6.16	12.32	6.97	2.57
TG 8	---	---	---	---	---
TG 9	11.10	-36.76	12.32	6.97	2.57
High Emitters	-2.75	-6.62	12.32	8.86	-2.12

Baseline mg/mi

	Exh VOC	Exh ben	Ace	Form	But
TG 1	493	27.30	2.42	5.91	2.67
TG 2	404	22.39	1.99	4.85	2.19
TG 3	408	22.59	2.01	4.89	2.21
TG 4	771	42.72	3.79	9.25	4.18
TG 5	317	17.58	1.56	3.81	1.72
TG 6	354	19.64	1.74	4.25	1.92
TG 7	689	38.20	3.39	8.27	3.74
TG 8	---	---	---	---	---
TG 9	457	25.33	2.25	5.49	2.48
High Emitters	3075	190.65	15.01	29.58	43.97

Target Fuel mg/mi

	Exh VOC	Exh ben	Ace	Form	But
TG 1	537	27.35	2.72	6.33	2.99
TG 2	431	21.01	2.23	5.19	2.25
TG 3	452	23.69	2.25	5.23	2.38
TG 4	923	40.09	4.23	9.90	4.00
TG 5	375	15.35	1.75	4.07	1.76
TG 6	373	18.43	1.96	4.55	2.14
TG 7	765	35.85	3.81	8.85	3.83
TG 8	---	---	---	---	---
TG 9	508	16.02	2.53	5.87	2.54
High Emitters	2990	178.02	16.85	32.20	43.04

Table 4-2 Hypothetical TOG and Benzene Emissions						
	TOG (g/mi)		Benzene Fraction		Benzene (g/mi)	
Fuel	Normal	High	Normal	High	Normal	High
Base	0.50	2.0	5%	8%	0.025	0.16
Target	0.40	1.9	4%	7%	0.016	0.133

$$1.0\text{ g/mi} = F_N * TOG_{N,\text{ Base Fuel}} + F_H * TOG_{H,\text{ Base Fuel}}$$

where F_N is the fraction of normals and F_H is the fraction of highs. The TOG emission rates for normals and highs on base fuel ($TOG_{N,\text{ Base Fuel}}$ and $TOG_{H,\text{ Base Fuel}}$) can be obtained from Table 4-2, and the fraction of highs is just ($1-F_N$). Substituting these into the equation above gives:

$$1.0\text{ g/mi} = F_N*0.5 + (1-F_N)*2.0$$

Solving the above for F_N results in the fraction of normals being 0.667 and the fraction of highs being 0.333.

Using these fractions with the benzene emission rate for normals and highs, one can obtain the mean benzene emission rate for the target fuel presented in this example, i.e.,

$$BZ_{Flt,Target} = F_N*BZ_{N,Target} + F_H*BZ_{H,Target}$$

where $BZ_{Flt,Target}$ is the fleet-average benzene emission rate for the target fuel, $BZ_{N,Target}$ is the average benzene emissions from normal emitters operating on the target fuel, and $BZ_{H,Target}$ is the average benzene emissions from high emitters operating on the target fuel. Substituting the fraction of normals and highs calculated above and the benzene emission rates from Table 4-2, the following is obtained:

$$BZ_{Flt,Target} = 0.667*0.016 + 0.333*0.133 = 0.055\text{ g/mi (or 55 mg/mi)}$$

Note that this approach used the benzene emission rate for the target fuel directly without first adjusting the base fuel TOG levels for the target fuel.

As outlined in Appendix B, the emissions data presented in Table 4-2 can also be thought of in graphical terms, as illustrated in Figure 4-2. Using this presentation, the target fuel benzene emission level (in g/mi or mg/mi) can be thought of as a linear function of the

Hypothetical Benzene-TOG Curve

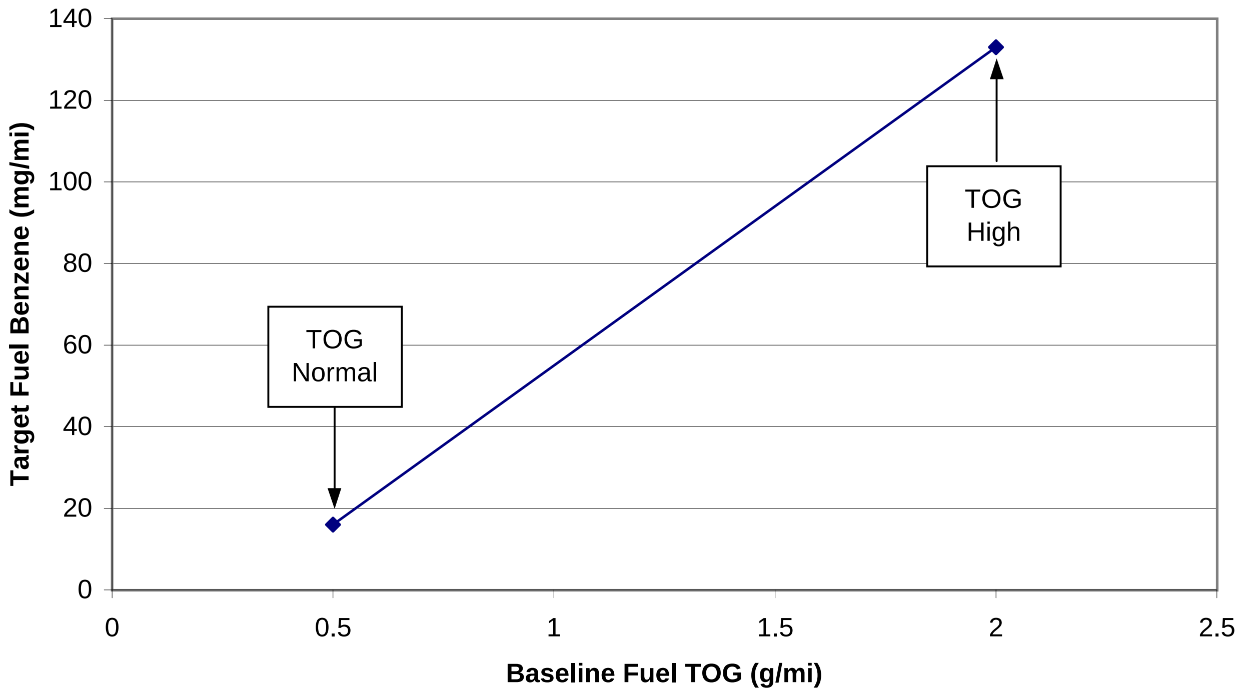

Figure 4-2

Benzene-TOG curve

baseline fuel TOG emission rate. The baseline fuel normal emitter TOG emission rate defines the lower end of the curve, while the baseline fuel high emitter TOG emission rate defines the upper end of the curve. Thus, the points plotted in Figure 4-2 are simply the values outlined in Table 4-2.

Based on the relationships presented in Appendix B, these "toxic-TOG curves" can be defined by an intercept (A) and a slope (B), according to the following:

$$A_{Target} = (TOG_{H, Base Fuel}*BZ_{N, Target} - TOG_{N, Base Fuel}*BZ_{H, Target})/(TOG_{H, Base Fuel} - TOG_{N, Base Fuel})$$

$$B_{Target} = (BZ_{H, Target} - BZ_{N, Target})/(TOG_{H, Base Fuel} - TOG_{N, Base Fuel})$$

where the TOG and BZ variables are those defined previously.

Using baseline fuel normal and high emitter TOG emission rates (in g/mi) and the target fuel normal and high emitter benzene emission rates (in mg/mi) defined in Table 4-2 as an example, the values of A and B are calculated as:

$$A_{Target} = (2.0*16 - 0.5*133)/(2.0 - 0.5) = -23.0$$

$$B_{Target} = (133 - 16)/(2.0 - 0.5) = 78.0$$

Using the above example of a fleet-average TOG emission rate of 1.0 g/mi on the base fuel, the fleet-average benzene emission rate (in mg/mi) is calculated as:

$$BZ_{Flt,\ Target} = A_{Target} + B_{Target}*TOG_{Flt,\ Base\ Fuel}$$

$$BZ_{Flt,\ Target} = -23.0 + 78.0*1 = 55.0 \text{ mg/mi}$$

which matches the calculation performed above.

An issue related to the above methodology is whether the linear assumption is valid for baseline TOG values above the high emitter point and below the normal emitter point. This is particularly relevant in cases where A and B values are determined from Tier 0 vehicles (e.g., the Complex model), but the results are applied to Tier 1 and LEV-category vehicles. For the simple example presented above, negative benzene emissions are estimated for the target fuel when the baseline fleet-average TOG emission rate falls below 0.295 g/mi. Thus, for fleet-average emission rates below (and above) the normal (and high) emitter values, a different methodology was needed. In those cases, it was assumed that the toxic emission rate was the same on a fractional basis. For the example above, the benzene emission rate for a baseline TOG value of 0.1 g/mi would be calculated as follows:

$$BZ_{(TOG=0.1\ g/mi)} = 0.1 \text{ g/mi} * (16 \text{ mg/mi BZ} / 0.5 \text{ g/mi TOG}) = 3.2 \text{ mg/mi}$$

This has the effect of forcing the toxic-TOG curve from the normal-emitter point back through the origin. The same approach is used in cases where the fleet-average baseline TOG emission rate is above the high emitter point.

The above approach was used to estimate toxic emissions as a function of baseline fuel TOG emission rates for all categories of vehicles. (For this analysis, industry average fuel defined in the 1990 Clean Air Act Amendments was considered the baseline fuel.) Rather than generating the A and B terms outside of the model, an input file was created with the normal and high emitter TOG emission rates (in g/mi) and the corresponding normal and high toxic emission rates (in mg/mi). This approach made the QC process much easier and only required a few lines of code to implement.

<u>Toxic-TOG Curves: Pre-Complex Model Vehicles</u> - For pre-complex model light-duty gasoline cars and trucks, heavy-duty gasoline vehicles, and Diesel vehicles, there are insufficient data with which to establish toxic emission rates as a function of normal and high emitters. As such, the toxic-TOG curves were generated by establishing the normal emitter point at the origin and the high emitter baseline TOG emission rate at 10 g/mi. The toxic emission rates corresponding to the 10 g/mi TOG value were then calculated from equations developed by EPA, many of which were updated from those developed for the 1993 MVRATS. A summary of these relationships is given in Appendix C.

As an example of the methodology used in this analysis, consider benzene emissions from a non-catalyst HDGV using a fuel with 1.2 vol% benzene and 31 vol% aromatics.

The equation relating the fuel parameters to the benzene level (as a percentage of TOG emissions) for non-catalyst HDGVs (from Appendix C) is as follows:

BZ %TOG = 0.8551 * vol% BZ + 0.12198 * vol% ARO - 1.1626

BZ %TOG = 0.8551 * 1.2 + 0.12198 * 31 - 1.1626 = 3.64%

Thus, if the high-emitter TOG emission rate is assumed to be 10 g/mi, the resulting benzene emission rate would be:

$BZ_{\text{High Emitter}}$ = 10 g/mi * 0.0364 = 0.364 g/mi (or 364 mg/mi)

For cases in which the target fuel contained an oxygenate or an RVP level below the baseline fuel assumption (i.e., 8.7 psi),[*] the TOG emission rate was decreased to account for that effect prior to generating the toxic pollutant emission point. The corrections used to model those impacts were provided by EPA and are summarized in Table 4-3.

Table 4-3
TOG Oxygenate and RVP Adjustments for Non-Complex Model Vehicles

Fuel Parameter	Non-Catalyst Vehicles	Oxidation Catalyst Vehicles
Oxygen, per 1 wt%	- 1.6%	- 4.46%
RVP, per 1 psi decrease	- 1.8%	- 1.7%

The methodology described above was applied to all technology groups and vehicle classes that were not evaluated with the Complex model. Open-loop three-way catalyst technologies, which are not evaluated by the Complex model, were treated as open-loop oxidation catalyst vehicles for this analysis. (Note that this technology was used only during the early 1980s, and it never accounted for more than 20% of the light-duty vehicle fleet in any model year.) Technology-specific toxic emission rates were developed based on a 10 g/mi TOG emission rate, and model-year-specific technology fractions (described later in this section of the report) were used to compile model-year-specific toxic-TOG curves.

<u>Toxic-TOG Curves: Tier 0 Vehicles</u> - The toxic-TOG curves developed for closed-loop Tier 0 vehicles made use of the unconsolidated Complex model provided to Sierra by

[*] Note that the RVP effect was applied only during the spring and summer evaluation periods. That is because the impact of RVP on exhaust emissions is generally thought to be a result of canister purge. Thus, under cold temperature conditions, this effect would be mitigated.

EPA. (All open-loop technologies were analyzed as described above.) The Complex model provides emissions estimates for eight different technology groups plus high emitters. For this study, the Complex model technology groups were collapsed to be consistent with available data on the fleet make-up (based on MOBILE5a definitions). The mapping between the Complex model technology groups and the technology groups utilized in this analysis was suggested by EPA (see Appendix D) and is summarized in Table 4-4.

Table 4-4
MOBILE5a and Complex Model Technology Group Mappings

MOBILE5a Tech Group	Complex Model Tech Groups
Carbureted (3W and 3W+OX)	9
3W PFI	Average of 1, 2, and 5
3W TBI	Average of 3 and 6
3W+OX PFI	4
3W+OX TBI	7
High Emitters (All Technologies)	High Emitter

The first step in this part of the analysis was to develop baseline fuel TOG emission rates for normal and high emitters in the Complex model. Because the Complex model exhaust hydrocarbon emissions estimates are based on volatile organic carbon (VOC) emissions (VOC = TOG - methane - ethane), a conversion to TOG was necessary. This was based on conversion factors provided by EPA, which recommended that toxic fractions based on VOC be scaled by a factor of 0.8079 for three-way catalyst vehicles and a factor of 0.7166 for three way + oxidation catalyst vehicles. Alternatively, dividing VOC emissions by these factors results in TOG emission estimates. Thus, after combining the technology groups as described in Table 4-4, the resulting VOC emission rates were converted to a TOG basis. These are shown in Table 4-5.

From this point, it is a simple matter of running the Complex model for the fuel parameters being analyzed and compiling the resulting toxics emission rates for each technology group. The model-year-specific emission rates (both TOG and toxics) for normal emitters were then developed by weighting the technology-specific Complex model results by the fraction of each technology in the fleet. A sample of this calculation is shown for TOG and benzene in Table 4-6 for 1988 model year LDGVs evaluated with 1990 Chicago summertime fuel parameters. Note that the four values in the lower right corner of the table shown in bold print would be used to establish the normal and high emitter points on the benzene-TOG curve for this model year and vehicle class. The same methodology was used for the remaining model years that had Tier 0 vehicles equipped with closed-loop technology.

Table 4-5 Mean Complex Model Base Fuel VOC and TOG Emission Rates by Technology Group		
MOBILE5a Tech Group	Mean VOC (g/mi)	Mean TOG (g/mi)
Carbureted (3W and 3W+OX)[a]	0.457	0.638
3W PFI	0.405	0.501
3W TBI	0.381	0.472
3W+OX PFI	0.771	1.076
3W+OX TBI	0.689	0.961
High Emitters (All Technologies)[b]	3.075	4.034

[a] The VOC-to-TOG correction was based on 3W+OX technology for this group.
[b] The VOC-to-TOG correction was based on an average of 3W and 3W+OX technology groups for high emitters.

Table 4-6 Sample Calculation Used to Develop the Toxic-TOG Curve for Benzene 1988 Model Year LDGV - 1990 Chicago Summertime Fuel			
Tech Group	Fraction	TOG (g/mi)	Benzene (mg/mi)
Carbureted	0.101	0.638	16.02
3W PFI	0.444	0.501	21.24
3W TBI	0.327	0.472	21.06
3W+OX PFI	0.048	1.076	40.09
3W+OX TBI	0.080	0.961	35.85
Normal Emitters	**--**	**0.570**	**22.73**
High Emitters	**--**	**4.034**	**178.02**

Toxic-TOG Curves: Tier 1 Vehicles - For Tier 1 vehicles, the normal-emitter point developed according to the methodology described above for closed-loop Tier 0 vehicles was modified to reflect the fact that Tier 1 vehicles are certified to more stringent hydrocarbon standards. Based on a review of information presented at the July 1992 MOBILE5a workshop, Tier 0 vehicles (which are certified to a 0.41 g/mi total hydrocarbon standard) have an effective NMHC standard of 0.377 g/mi. Tier 1 vehicles are certified to 0.25 g/mi NMHC. Thus, the lower point on the toxic-TOG curve developed from the Complex model was adjusted by the ratio 0.25/0.377. This correction was used for both cars and trucks, since the Complex model relationships were based on data from cars and trucks, and similar fractional NMHC reductions occur between Tier 1 and Tier 0 vehicles. Because there is no information to suggest that Tier 1 high emitters will be substantially different than Tier 0 high emitters (although there should be fewer of them), the high-emitter point on the toxic-TOG curve was left unchanged.

Toxic-TOG Curves: LEV-Category Vehicles - As with Tier 1 vehicles, the high-emitter point on the toxic-TOG curves remained the same for LEVs as that calculated for Tier 0 vehicles. (It is too early to determine if high-emitting LEVs will be significantly different than high-emitting Tier 0 vehicles.) However, the normal-emitter point on the toxic-TOG curve required an adjustment for gasoline sulfur level in addition to that made for the standards differences.

The baseline fuel normal-emitter TOG point was corrected to account for LEV standards by applying a ratio of standards to the Tier 0-based Complex model value for each technology type. As described above, the Tier 0 "effective" NMHC standard is 0.377 g/mi. LEVs are certified to 0.075 g/mi nonmethane organic gas (NMOG), so an approach to correct this to an equivalent NMHC basis was needed. This correction was based on similar corrections developed by EPA and presented at the July 1992 MOBILE5 workshop. Three corrections were applied to the 0.075 g/mi NMOG value: (1) a straight NMOG to NMHC correction to remove "organic" gases (0.075 → 0.0728); (2) a correction to account for the fact that CARB-certified LEVs receive a reactivity adjustment of 0.94[10] (0.0728 →0.0775); and (3) a correction to account for the difference between California certification fuel and federal certification fuel (0.0775 →0.0880). Using the TW PFI technology group as an example (0.501 g/mi TOG, from Table 4-5), the resulting TOG normal emitter point was calculated to be:

$$TOG_{LEV\text{-}3W\ PFI} = 0.501 * (0.088/0.377) = 0.117 \text{ g/mi}$$

Note that this reflects the LEV TOG emission rate on baseline fuel with 339 ppm S.

To generate toxics emission rates as a function of fuel parameters, several steps were required. Because LEVs have been shown to have a stronger response to gasoline sulfur levels than Tier 0 vehicles, the Complex model results could not be used directly in the calculations. Instead, the Complex model was used to determine the non-sulfur fuel corrections, while the sulfur equations provided by EPA (described in Section 3 of this report) were used to determine the LEV-specific sulfur corrections. The specific calculations in this analysis are illustrated with the example below.

Using the fuel parameters from the 1990 Chicago summer example above, the normal emitter target fuel benzene emission rate for the 3W PFI technology group was calculated as follows. (Although LEVs will not necessarily be operated on this fuel, it serves as a good example.) First, it was assumed that the LEV sulfur effect would impact the TOG mass and the toxics mass equally. Thus, the toxics mass fraction for the fuel being analyzed was determined by simply taking the ratio of the target fuel toxic emission rate to the target fuel TOG rate calculated by the Complex model. In the case of benzene for this example, this was 0.02124/0.5539 = 3.835%.

The next step of the analysis was to determine the impact that the fuel modifications would have on the LEV TOG emission rate. This was estimated by determining the non-sulfur TOG correction from the Complex model and the sulfur TOG correction from the EPA equations. The non-sulfur Complex model correction was determined by calculating the target fuel TOG emission rate with a sulfur level of 339 ppm. For this example, the target fuel non-sulfur TOG emission rate was 0.505 g/mi (compared to a baseline of 0.501 g/mi). Thus, the non-sulfur correction for this fuel was calculated as follows:

$$TOG_{LEV/Non\text{-}S} = 0.117 \text{ g/mi} * (0.505/0.501) = 0.118 \text{ g/mi}$$

The sulfur correction was applied next. In this example, the in-use sulfur level was 512 ppm. Thus a correction from 339 to 512 ppm was developed from the EPA equations. This amounted to a multiplicative factor of 1.107. Applying this factor to the non-sulfur TOG emission rate, the following is obtained:

$$TOG_{LEV/S\text{-}corrected} = 0.118 \text{ g/mi} * 1.107 = 0.131 \text{ g/mi}$$

The benzene emission rate was then determined by applying the previously calculated benzene fraction to the above TOG emission rate:

$$BZ_{Target} = 0.131 \text{ g/mi} * 0.03835 = 0.00502 \text{ g/mi (or 5.02 mg/mi)}$$

Thus, for this fuel, the bottom point of the benzene-TOG curve would be 0.501 g/mi TOG and 5.02 mg/mi benzene.

Technology Fractions - Because toxics emissions and toxics fractions are a function of technology, the model-year-specific toxic-TOG curves developed for this study were generated by weighting technology-specific emissions by the estimated sales mix of each technology as a function of model year. For gasoline-fueled vehicles, the following technology types were considered:

- Open-loop, non-catalyst;
- Open-loop, catalyst;
- Closed-loop, carbureted;
- Closed-loop, three-way catalyst, PFI;
- Closed-loop, three-way + oxidation catalyst, PFI;
- Closed-loop, three-way catalyst, TBI; and
- Closed-loop, three-way + oxidation catalyst, TBI.

For pre-1991 model year light-duty cars and trucks and all heavy-duty gasoline vehicles, the technology fractions were based on those developed by EPA for MOBILE5a. Technology fractions for 1992 and later model year LDGV, LDGT1, and LDGT2 categories were derived from a recent report prepared in support of MOBILE6.[11] However, because that study did not report PFI and TBI technologies separately for 1996 and later model year LDGTs, Sierra had to make assumptions regarding the phase-out of TBI technology. In this analysis it was assumed that TBI technology on light-duty gasoline trucks would be phased-out under the NLEV program (i.e., by the 2001 model year for non-OTR states). The technology distribution for LDGTs for the 1996 to 2000 model years was estimated by interpolating between the 1995 and 2001 values. The final model-year-specific technology fractions used in this study are summarized in Appendix E.

Aggressive Driving Correction - The vast majority of data and models related to motor vehicle air toxics is based on FTP testing. However, to be consistent with the approach taken in the MOBILE modeling (i.e., T2AT) for the Tier 2 Study, EPA recommended that an adjustment for aggressive driving behavior be applied to the toxics estimates developed in this work assignment. This adjustment can be thought of as two discrete steps: (1) an adjustment (i.e., increase) to the TOG mass to account for off-cycle operation, and (2) an adjustment (increase or decrease) to account for the difference in mass fraction of each toxic compound of interest between the FTP and the Unified Cycle (UC). The UC, or LA92, is used here because that is the cycle upon which the TOG aggressive driving corrections were developed for the T2AT model.

The methodology used to apply an aggressive driving correction to the toxics estimates for this study is best illustrated with an example. Consider a case in which the Tier 1 vehicle FTP-based TOG emission rate is 0.5 g/mi and the benzene mass fraction is 5%. Assume that the benzene mass fraction on the Unified Cycle is 7%. Using the off-cycle correction factors developed by EPA for this effort, the TOG emission rate, corrected for aggressive driving behavior, would be as follows:

$$TOG_{UC} = OCCF_{Agg} * TOG_{FTP}$$

$$TOG_{UC} = 1.29 * 0.5 \text{ g/mi} = 0.645 \text{ g/mi}$$

where 1.29 is the aggressive driving correction for Tier 1 vehicles that have not been certified to the SFTP regulations. (See Table 3-3 earlier in this report.)

In this example, the benzene emission rates over the two cycles would be:

$$BNZ_{FTP} = 0.5 \text{ g/mi} * 0.05 = 0.025 \text{ g/mi}$$

$$BNZ_{UC} = 0.645 \text{ g/mi} * 0.07 = 0.045 \text{ g/mi}$$

where BNZ_{UC} reflects the "in-use" benzene emission rate corrected for aggressive driving behavior.

Continuing with this example, an off-cycle toxics adjustment factor can be developed from the ratio of the benzene fraction over the UC to the benzene fraction over the FTP:

$$ADJ_{BNZ,UC/FTP} = x_{BNZ,UC}/x_{BNZ,FTP}$$

$$ADJ_{BNZ,UC/FTP} = 0.07/0.05 = 1.4.$$

Based on the Toxic-TOG curve approach described above (in which the FTP-based TOG emission rate is used to establish the FTP-based toxic emission rate), determining the FTP-based toxic emission rate is the first step in the overall calculation of in-use toxic emission rates. Thus, in the example presented here, the starting point would be BNZ_{FTP} = 0.025 g/mi. This value would then need to be corrected for aggressive driving behavior (both for the TOG mass increase and the differential mass fraction between the FTP and the UC), as shown below.

$$BNZ_{UC} = BNZ_{FTP} * ADJ_{Aggressive\ Driving} * ADJ_{BNZ,UC/FTP}$$

$$BNZ_{UC} = 0.025\ g/mi * 1.29 * 1.4$$

$$BNZ_{UC} = 0.045\ g/mi$$

which corresponds with the "in-use" benzene emission rate in the example presented above.

Using data collected by CARB in which vehicles were tested on both the FTP and the UC, off-cycle toxics adjustment factors were developed for benzene, acetaldehyde, formaldehyde, 1,3-butadiene, and MTBE based on the ratio of the toxic mass fraction over the UC to the toxic mass fraction over the FTP. A complete description of the database provided by CARB and the analysis performed for this study is contained in Appendix F, and a summary of the results follows.

Summary of Analysis of CARB Off–Cycle Data - CARB provided speciated data for 18 FTP and UC test "pairs." The 18 test pairs reflect test results for a total of 13 vehicles while operating on one or more of 3 test fuels (Indolene, commercial unleaded gasoline, and California Phase 2 reformulated gasoline). Test results for one vehicle were eliminated from all off–cycle toxics analyses because the FTP and UC test fuels were not the same. Furthermore, to ensure that analysis results were not unduly biased by any one particular vehicle, all test pairs applicable to a single vehicle were collapsed into a single test pair by arithmetically averaging individual FTP and UC test results. With one exception, test fuel sensitivities were not considered in the off–cycle analysis (i.e., all test fuels were treated as a group) due to insufficient data. However, since analysis results are expressed in a normalized form as the ratio of UC data to FTP data, most fuel–related distinctions should be controlled. A single exception was made for MTBE emissions, where test results for zero MTBE content fuels (i.e., Indolene and one commercial unleaded gasoline) were excluded from the estimation of UC to FTP ratios (for MTBE only). Following this approach, the CARB database was collapsed into eight normal THC emitter test pairs (seven for MTBE) and four high THC emitter test pairs.

Basic statistical regression analysis was performed on the CARB test data, primarily as a quality assurance tool. The size of the normal and high emitter databases was sufficiently small to prohibit the development of robust UC/FTP relationships through detailed statistical analysis. Nevertheless, regression analysis was undertaken to check for data consistency and the likelihood of an additive component (i.e., an emissions offset) in UC/FTP relationships. For all species subjected to regression analysis (TOG, benzene, 1,3–butadiene, MTBE, formaldehyde, and acetaldehyde), the intercept terms in regressions of UC emissions versus FTP emissions were not significant at the 95 percent confidence level. Moreover, regression of the UC toxics fraction of TOG versus the FTP toxics fraction of TOG for all five toxics species yielded similar results (i.e., insignificant intercepts). Based on these results, it is unlikely that an additive component exists, and the ratio of average UC test results to average FTP test results should provide a reasonable estimation of UC/FTP emissions relationships. Therefore, the required UC/FTP off–cycle toxics adjustment factors ($ADJ_{UC/FTP}$, as described above) were calculated as the ratio of the mean of the toxics fractions over the UC to the mean of the toxics fractions over the FTP. Appendix F provides additional detail on the basis for the use of means, but in general calculated mean ratios were consistent with zero-intercept regression coefficients to within an error of ±5 percent. Table 4-7 presents the specific normal and high emitter off–cycle adjustment factors used for the toxics emissions analysis.

Table 4-7
Ratio of UC Toxics Fraction to FTP Toxics Fraction

Toxic Species	Normal THC Emitters	High THC Emitters
Benzene	1.315	1.126
1,3-Butadiene	1.037	0.708
MTBE	0.825	0.965
Formaldehyde	1.163	0.894
Acetaldehyde	1.020	0.919

Off–cycle adjustment factor development was obviously hampered by the limited amount of data available for analysis. Ideally, separate adjustment factors would be developed for the different vehicle technologies and classes represented in the fleet as well as the different fuels encountered in-use. However, independent adjustment factor development was not possible given that only eight normal emitter test pairs (six LDVs and two LDTs covering the 1984 through 1996 model years) and four high emitter test pairs (three LDVs and one LDT covering the 1982 through 1987 model years) were available for analysis. As a result, there was little alternative but to treat the database in the aggregate, and develop a single set of adjustment factors for normal and high emitters which could subsequently be weighted to develop unique model-year- and vehicle-class-specific adjustments. Before this aggregate treatment, however, a basic regression analysis was conducted on the 12 test pairs to determine whether a significant age-based relationship was evident in the test data. The resulting regression coefficients were not significant for any of the five emissions species examined; therefore, the aggregate treatment was deemed acceptable and the normal and high emitter adjustment factors presented in Table 4-7 were used without change for all 1981 and later gasoline-powered vehicles.

Because no data were available with which to generate factors for pre-1981 vehicles, two different approaches were considered. First, because most of the pre-1981 model year vehicles in the emissions analyses performed for this study would be high emitters based on their HC emission rates, one possibility is to simply assign pre-1981 vehicles the high-emitter factor. Alternatively, because no data exist on pre-1981 vehicles, it can also be argued that a factor of 1.0 is appropriate. Because of the uncertainty involved in this analysis, pre-1981 model year vehicles were assigned a value of 1.0 for the off-cycle toxics factor.

For 1995 and later model year vehicles, the HC emission factors are such that few high emitters are assumed to exist in the fleet, particularly for the I/M cases. Because of that, the off-cycle toxics factor for these vehicles was assumed to be equal to the normal emitter factor in Table 4-7.

For 1981 to 1994 model year vehicles, the normal and high emitter adjustment factors in Table 4-7 were weighted according to the anticipated contribution of normals and highs to the FTP-based HC emission rate. Because this is dependent on the calendar year of analysis and whether an I/M program is in effect, a series of different factors were developed. This was accomplished by forecasting the HC base emission rate equations provided by EPA using the odometer level expected in 1990, 1996, and 2007. (The BERs are discussed in detail in Section 3 of this report.) The methodology used to perform this analysis is similar to that described in Section 3 for the implementation of normal and high emitter CO oxygenate impacts; an example of the calculation follows.

The mean HC emission rate of the normal and high emitters in the FTP/UC sample was 0.23 g/mi and 1.77 g/mi, respectively. A 1984 model year vehicle, evaluated in 1996, would have an average emission rate of 1.4 g/mi. Thus, the fraction of normals (using the FTP/UC sample definition) can be calculated from the equation shown below.

$$1.4 \text{ g/mi} \quad = \quad 0.23*N + 1.77*(1-N)$$

Solving for N, one arrives at 24% normals and 76% highs, with normals contributing 3.9% to the 1.4 g/mi emission rate (i.e., (0.23*0.24)/1.4). Thus, for this case, the weighted UC/FTP factor for benzene would be:

$$ADJ_{BNZ,UC/FTP} = 0.039*1.315 + 0.961*1.126 = 1.133$$

This methodology was used to develop the UC/FTP toxics factors for 1981 to 1994 model year light-duty vehicles for 1990, 1996, and 2007 non-I/M cases, and for 1990 and 1996 I/M cases. (The 1996 I/M case was used for the 2007 and 2020 runs, consistent with the approach that EPA used to develop the off-cycle correction factors.) The results are summarized in Appendix A with the TOG off-cycle corrections.

Air Conditioning Usage - For the quarters in which air conditioning is likely to be used (i.e., spring and summer), an additional correction to the in-use toxic emission rates was applied. Because air conditioning usage results in a relatively constant load on the engine, it was assumed in this analysis that the FTP-based toxic fractions will apply to the increased TOG mass as a result of air conditioning usage. Under this assumption, the FTP-based toxic emission rate can be used directly in the calculation. Thus, the increase in toxic emissions as a result of air conditioner usage was calculated as the difference between the toxic emission rate with the full off-cycle correction applied (i.e., aggressive driving + A/C) and the toxic emission rate with only an aggressive driving component included. For the example above (i.e., a Tier 1 vehicle not certified to the SFTP regulations), the two correction factors are calculated as follows.

$$ADJ_{Agg\ Drv} = 1.29$$

$$ADJ_{Agg\ Drv\ +\ A/C} = 1.29 * 1.04 = 1.342$$

Using the example above, the increase in benzene emissions as a result of air conditioning usage would be calculated as shown below.

$$BNZ_{A/C} = BNZ_{FTP} * (1.342 - 1.29)$$

$$BNZ_{A/C} = 0.025\ g/mi * (1.342 - 1.29) = 0.0013\ g/mi$$

This result is then added to the BNZ_{UC} value calculated above for an overall in-use benzene emission rate. At this point, the MOBILE model takes over and completes the calculations (e.g., temperature corrections, travel fraction weighting, etc.).

Code Changes Required to Implement the Revised Exhaust Emissions Methodology - The original T2ATTOX code provided by EPA was modified to implement the methodologies described above. The original code structure ran the model for one toxic emission factor at a time. We modified the structure so that all toxic emission factors could be generated within the same run. This change was made to the subroutine

HCCALX. In addition, the original code required that a multiplicative factor be input for each toxic so that the ratio reflected the toxic emission rate per TOG exhaust emission rate (i.e., it was structured to perform estimates by applying the toxic fraction to the calculated TOG emission rates). This factor was used for all emission levels for a particular model year and vehicle type. In the version of the model developed in this study, the toxic-TOG relationship was described separately for low and high emitters in terms of mg/mi toxic versus g/mi TOG. The TOG emission factor developed for a particular run was then used to interpolate between the two relationships. This change was implemented in the TOXADJ subroutine.

Other code changes were made to the GETTX2 routine to read in the toxic-TOG curves, the aggressive driving factors, and the air conditioning factors. The OFFCYC subroutine was modified to perform the aggressive driving and air conditioning corrections described above. The BEF subroutine was modified to add calls to the TOXADJ and OFFCYC subroutines. Two output routines (OUTDT3 and OUTDT4) were modified so that all the toxic emission factors could be printed for each run. Subroutines SAVER and ADJUST were modified so that the new toxic emission factors could be saved and corrected for cases in which July runs were requested. For July runs the model is run twice, once with the preceding Calendar year and then with the succeeding year. The two runs need to saved and averaged for the July output. A listing of the subroutines modified for this effort is presented in Appendix G, along with a description of how the model is run.

For acetaldehyde, formaldehyde, and 1,3-butadiene, crankcase emissions from tampered vehicles are included in the exhaust emissions. For benzene and MTBE, the crankcase emissions are calculated with hot-soak and diurnal emissions. Crankcase emissions from correctly operating vehicles are zero, but for vehicles with inoperable PCV valves, emissions need to be estimated. These emissions are calculated for all toxic compounds and occur as combustion gases blow by the piston into the engine crankcase, so these emissions are similar to exhaust emissions. The exhaust toxic fractions are applied for estimating the toxic emission factors from crankcase emissions.

Evaporative Emissions

The only toxics included in the evaporative emissions estimates were benzene and MTBE. For this analysis, the methodology originally developed for the T2ATTOX model to estimate evaporative toxics estimates was used directly. In that method, the mass fraction of benzene and MTBE (as a percent of total TOG emissions) is applied to the evaporative TOG emissions estimates calculated by the MOBILE model.

The toxics fractions used in this analysis were based on the fuel property data specific to each area and control scenario and the toxic-to-evaporative emissions relationships provided by EPA (which came from the Complex model). A summary of the equations relating fuel parameters to evaporative toxics fractions is given in Table 4-8 for each of the evaporative processes modeled by MOBILE. Since the Complex model does not calculate resting loss emissions, it was assumed that the benzene and MTBE fractions were equal to those of diurnal emissions. Note that two sets of equations are given for

MTBE. That is because a "high" and "low" evaporative MTBE estimate is included in the MTBE model developed by EPA. Based on direction from EPA, the "high" MTBE fractions were used in this analysis.

Table 4-8
Evaporative Benzene and MTBE Fraction Equations from the Complex Model and EPA's MTBE Model

Pollutant	Process	Toxic Fraction Equation (% of TOG)
Benzene	Hot Soak	(-0.03420*OXY - 0.080274*RVP + 1.4448)*BNZ
	Diurnal	(-0.02895*OXY - 0.080274*RVP + 1.3758)*BNZ
	Running	(-0.03420*OXY - 0.080274*RVP + 1.4448)*BNZ
	Resting	(-0.02895*OXY - 0.080274*RVP + 1.3758)*BNZ
	Refueling	(-0.02955*OXY - 0.081507*RVP + 1.3972)*BNZ
MTBE (High)	Hot Soak	(24.205 - 1.746*RVP)*MTBE/10
	Diurnal	(22.198 - 1.746*RVP)*MTBE/10
	Running	(17.8538 - 1.6622*RVP)*MTBE/10
	Resting	(22.198 - 1.746*RVP)*MTBE/10
	Refueling	1.743*MTBE*(-0.02955*OXY - 0.081507*RVP + 1.3972)
MTBE (Low)	Hot Soak	((31.442 - 1.746*RVP)/1.8029)*MTBE/10
	Diurnal	((31.442 - 1.746*RVP)/2.3191)*MTBE/10
	Running	((31.412 - 1.6622*RVP)/4.9963)*MTBE/10
	Resting	((31.442 - 1.746*RVP)/2.3191)*MTBE/10
	Refueling	1.743*MTBE*(-0.02955*OXY - 0.081507*RVP + 1.3972)

Note: OXY = wt% oxygen
RVP = Reid vapor pressure in psi
BNZ = vol% benzene
MTBE = vol% MTBE

As with the exhaust emission factors, evaporative emission factors developed above were read into the modified T2ATTOX model through subroutine GETTX2. The evaporative fractions were developed for Benzene and MTBE for each of the evaporative components described above. These fractions were then used to develop the evaporative toxic emission factors in the subroutine EVPADJ. EVPADJ is called from the subroutine HCCALX for each of the evaporative processes and for each toxic. The primary change in the new model is that the evaporative emission factors for both the toxics are calculated in the same run, rather than in separate runs.

Diesel Particulate Emissions

Estimating Diesel particulate matter (PM) emission rates proved to be a much more straightforward process than for the other toxic compounds considered in this study. For this analysis, EPA's PART5 model was used directly. PART5 is similar in structure and function to the MOBILE series of models, calculating exhaust and non-exhaust (e.g., road dust) particulate emissions for each vehicle class included in the MOBILE models. Only exhaust PM emission rates from Diesel vehicles were included in this analysis, and a particle size cut-off of 10 μm was specified in the model inputs.

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5. DEVELOPMENT OF AREA-SPECIFIC MODEL INPUTS

The next step in estimating toxic exposure and risk estimates was to run the modified T2ATTOX model. This required the development of input files specific to each area, calendar year, season, and control scenario. As outlined above, nine urban areas and four calendar years were evaluated in this study. For two of those calendar years (1990 and 1996), four seasons and a baseline control scenario were modeled. For the two forecast years (2007 and 2020), four seasons and four control scenarios were modeled. For each of these 360 modeling runs, it was necessary to determine the inputs needed and develop input files for the revised T2ATTOX model. Because of the large number of modeling runs, it was necessary to automate the process of constructing the input files as much as possible to minimize potential errors in developing those inputs.

The input files for the revised T2ATTOX model include the same information required in a standard MOBILE5b run. Some of the inputs that were important to determine for each urban area included in this study were the registration distributions, inspection and maintenance program parameters (start year, stringency level, program type and frequency, and vehicles tested), fuel RVP levels, and temperatures.

To determine all of the necessary input parameters for each city, several sources were used. The first source of information was a group of input files developed by E. H. Pechan (called the Trends input files[12]) which were provided to Radian and Sierra by EPA. The Trends MOBILE5b input files were developed for 13 selected areas, which include the nine areas considered for this study. There were several Trends files for each of the nine areas that represent different counties within that area. However, for this analysis, only one file per area was desired. Therefore, it was necessary to choose one county from each of the Trends files that best represented the city considered for the study. Table 5-1 shows the cities considered in this study and the counties that were selected from the Trends input files for each of these cities.

Specific MOBILE Inputs for This Study

Radian used the Trends input files and other information provided by EPA to determine the area-specific input parameters. These parameters included registration fractions, VMT mix, alternate basic emission rates (discussed in Section 3), inspection and maintenance program parameters, Stage II refueling controls, and local area parameter record inputs (fuel RVP and calendar year of evaluation). Summarized below are the specific inputs used in this analysis.

Table 5-1
Trend Files and Counties Selected for Each Modeled Urban Area

Urban Area	Counties	Name of Selected Trends File
Chicago	Cook, DuPage, and Lake Counties	M9617031.IN
Denver	Adams, Arapahoe, Boulder, Denver, and Jefferson Counties	M9608001.IN
Houston	Harris County	M9648201.IN
Minneapolis	Anoka, Carver, Dakota, Hennepin, Ramsey, Scott, and Washington Counties	M9627003.IN
New York City	Bronx, Kings, Nassau, New York, Queens, Richmond, Rockland, Suffolk, and Westchester Counties	M9636005.IN
Philadelphia	Bucks, Chester, Delaware, Montgomery, and Philadelphia Counties	M9642017.IN
Phoenix	Maricopa County	M9604013.IN
Spokane	Spokane County	M9653063.IN
St. Louis	Jefferson, St. Charles, St. Louis Counties, and St. Louis City	M9629099.IN

Registration Fractions - The registration fractions were determined for each city from two sources. For the 1990 and 1996 modeling runs, the information provided for each city in the Trends input files was used. For the 2007 and 2020 modeling runs, the registration fractions included with the T2AT model were used. These registration fractions were determined during the Tier II study.

VMT Mix - For the 1990 calendar year runs, the MOBILE5b default VMT mix was used. For the 1996 runs, EPA provided alternate VMT fractions for light-duty gas vehicles (LDGVs), light-duty gas trucks 1 (LDGT1s), and light-duty gas trucks 2 (LDGT2s) based on the Tier 2 study. These 1996 VMTs for LDGVs, LDGT1s, and LDGT2s were combined with the default 1996 VMT mix from MOBILE5b for the other five vehicle classes to determine the VMT mix for 1996.

The VMT mixes for the baseline runs in 2007 and 2020 were calculated in a similar way. The VMT split for the LDGVs, LDGT1s, and LDGT2s were previously developed by EPA for the Tier 2 Study. These numbers were combined with the MOBILE5b defaults for 2007 and 2020 to determine the baseline VMT mixes for 2007 and 2020.

For the increased light-duty Diesel truck penetration scenario in 2007 and 2020, the VMT fractions for LDGT1s, LDGT2s, and LDDTs were provided by EPA. These fractions simply replaced those calculated for the baseline 2007 and 2020 runs. Table 5-2 shows the VMT fractions each of the calendar years and scenarios.

Table 5-2 VMT Fractions Used for the Toxics Analysis									
Year	Scenario	LDGV	LDGT1	LDGT2	HDGV	LDDV	LDDT	HDDV	MC
1996	Baseline	0.550	0.225	0.107	0.035	0.003	0.002	0.070	0.008
2007	Baseline	0.435	0.303	0.144	0.032	0.002	0.002	0.077	0.005
2020	Baseline	0.391	0.333	0.158	0.031	0.002	0.004	0.077	0.004
2007	Increased Diesel	0.435	0.230	0.110	0.032	0.002	0.109	0.077	0.005
2020	Increased Diesel	0.391	0.185	0.087	0.031	0.002	0.223	0.077	0.004

Alternate TOG BERs - As discussed in Section 3, alternate BER were provided by EPA for these modeling runs. Depending on the control scenario being modeled, these alternate BERs were included in the input file. Table 5-3 shows the alternate BER files which were used for each city, year, and scenario. Print-outs of these files are shown in Appendix A.

Inspection and Maintenance (I/M) Program Parameters - The I/M program parameters were determined from several sources. The first source was the Trends input files developed by E.H. Pechan. Several pieces of information were also provided by EPA, including the following:

- Alternate credit files for 1981 and newer vehicles;[13]
- An internal document listing I/M test type for each city and calendar year;[14] and
- A table outlining primary modeling elements for operating I/M programs throughout the U.S.[15]

These four sources of information were used to determine the I/M program parameters for this study. The I/M program parameters included the start year of the program, test type, model years tested, vehicles tested, test frequency, test facility, waiver rates, and compliance rate. In addition, the tampering rates calculated by MOBILE5b were zeroed out for I/M areas evaluated in 2007 and 2020. This is consistent with the approach taken in the Tier 2 Study.

Table 5-3 BER Input Files Used for Each Study Areas					
City	Scenario	1990	1996	2007	2020
Chicago	Baseline	NTR_IM_B.BER	NTR_IM_B.BER	NTR_IM_B.BER	NTR_IM_B.BER
	SC#1			NTR_IM_B.BER	NTR_IM_B.BER
	SC#2,#3			NTR_IM_C.BER	NTR_IM_C.BER
Denver	Baseline	DNV_IM_B.BER	DNV_IM_B.BER	DNV_IM_B.BER	DNV_IM_B.BER
	SC#1			DNV_IM_B.BER	DNV_IM_B.BER
	SC#2,#3			DNV_IM_C.BER	DNV_IM_C.BER
Houston	Baseline	NTR_NO_B.BER	NTR_NO_B.BER	NTR_IM_B.BER	NTR_IM_B.BER
	SC#1			NTR_IM_B.BER	NTR_IM_B.BER
	SC#2,#3			NTR_IM_C.BER	NTR_IM_C.BER
Minn.	Baseline	NTR_IM_B.BER	NTR_IM_B.BER	NTR_NO_B.BER	NTR_NO_B.BER
	SC#1			NTR_NO_B.BER	NTR_NO_B.BER
	SC#2,#3			NTR_NO_C.BER	NTR_NO_C.BER
New York	Baseline	OTR_IM_B.BER	OTR_IM_B.BER	OTR_IM_B.BER	OTR_IM_B.BER
	SC#1			OTR_IM_B.BER	OTR_IM_B.BER
	SC#2,#3			OTR_IM_C.BER	OTR_IM_C.BER
Philly	Baseline	OTR_IM_B.BER	OTR_IM_B.BER	OTR_IM_B.BER	OTR_IM_B.BER
	SC#1			OTR_IM_B.BER	OTR_IM_B.BER
	SC#2,#3			OTR_IM_C.BER	OTR_IM_C.BER
Phoenix	Baseline	NTR_IM_B.BER	NTR_IM_B.BER	NTR_IM_B.BER	NTR_IM_B.BER
	SC#1			NTR_IM_B.BER	NTR_IM_B.BER
	SC#2,#3			NTR_IM_C.BER	NTR_IM_C.BER
Spokane	Baseline	NTR_IM_B.BER	NTR_IM_B.BER	NTR_IM_B.BER	NTR_IM_B.BER
	SC#1			NTR_IM_B.BER	NTR_IM_B.BER
	SC#2,#3			NTR_IM_C.BER	NTR_IM_C.BER
St. Louis	Baseline	NTR_IM_B.BER	NTR_IM_B.BER	NTR_IM_B.BER	NTR_IM_B.BER
	SC#1			NTR_IM_B.BER	NTR_IM_B.BER
	SC#2,#3			NTR_IM_C.BER	NTR_IM_C.BER

Start year - The Trends input files for the original I/M program start year were used to determine the I/M program start year. The only exception was for Minnesota's I/M program. According to the Trends input files, the program started in 1990; however, it was determined, based on information from the Minnesota DEQ, that the program actually started in July 1991. For each city, the same I/M program start year was used for all four calendar years of evaluation.

Test type - For test type, information provided by EPA was used. Table 5-4 shows the I/M test types that were provided by EPA. The only change to this information is in Minneapolis for the calendar year 1990. According to information receive from EPA, there was an I/M program 1990. However, as noted above, the I/M program did not start until July 1991. Thus, the 1990 runs performed for this analysis did not include an I/M program.

Table 5-4
I/M Test Type Information

City	1990	1996	2007	2020
Chicago	Idle	Idle	Final IM240	Final IM240
Denver	Idle	Phase-in IM240	Final IM240	Final IM240
Houston	No I/M	No I/M	Idle	Final IM240
Minneapolis	No I/M	Idle	No I/M	No I/M
New York	Idle	Idle	Phase-in IM240	Final IM240
Philadelphia	Idle	Idle	Phase-in IM240	Final IM240
Phoenix	Idle	Phase-in IM240	Final IM240	Final IM240
Spokane	Idle	Idle	Phase-in IM240	Final IM240
St. Louis	Idle	Idle	Final IM240	Final IM240

Model years tested - For the model years covered in each I/M program, the information provided in the Trends files was used. However, for LDGVs newer than 1994 and LDGTs newer than 1996, the I/M program benefit was included in the alternate BERs. Therefore, the I/M program in these input files was modeled to test only 1994 and older LDGVs and 1996 and older LDGTs.

Test facility, test frequency, and vehicles tested - For these three parameters, two sources of information were used. For the older calendar years (1990 and sometimes 1996), the information was determined from the Trends input files. For 2007 and 2020, information received from EPA was used instead.

Stringency, waiver rates, and compliance rates - The Trends input files were the only source of information that contained any specific information about these three input parameters.

Table 5-5 summarizes the source of information that determined each of the I/M program parameters for this study.

Table 5-5 I/M Program Parameters Information Sources by Calendar Year		
Parameter	Calendar Years	Source
Model Years Covered	1990, 1996, 2007, and 2020	Trends input files and information from EPA memo concerning alternate credit files and alternate BERs.[13]
Test type	1990, 1996, 2007, and 2020	Information provided by Dave Sosnowski.[14]
Start Year, Stringency, Waiver Rates, and Compliance Rate	1990, 1996, 2007, and 2020	Trends input files.
Test Facility, Test Frequency, and Vehicles Tested	1990	Trends input files.
	1996	Trends input files and information provided by Buddy Polovick (for Denver, Minneapolis, and Phoenix only).[15]
	2007 and 2020	Information provided by Buddy Polovick[15]

Evaporative System Functional Checks - One aspect of I/M that has been evolving over the last several years is related to evaporative system functional checks. The practical implementation of pressure and purge functional checks has had mixed success, and many areas of the country are now considering a functional check of only the gas cap, instead of the entire evaporative system.

For this study, evaporative control system functional checks in each area were modeled as shown in Table 5-6. That table shows a breakdown of pressure, purge, and gas cap tests for each city and calendar year used in this modeling. Two model year distinctions are made in the table. That is because 1997 and newer model year vehicles are equipped with enhanced evaporative control systems and onboard diagnostic (OBD) systems. (The phase-in of these requirements actually spans several model years – 1997 was chosen as a midpoint.) For this analysis, it was assumed that OBD would result in the identification and repair of malfunctioning evaporative control systems that would be on par with the pressure and purge test. At this point, however, this assumption is very subjective and may overstate the benefits of the OBD system. Currently, very few data exist on the in-use performance of OBD systems and the response of consumers to malfunction identification. In addition, it is likely that the failure rates of vehicles certified to the enhanced evaporative emission standards will decrease relative to the default values in MOBILE5b. Again, however, no data exist on the in-use performance of these systems. For areas without an I/M program in the future (i.e., Minneapolis) it was assumed that there is no benefit conferred by OBD.

Table 5-6
Evaporative Checks by Calendar Year and Modeled Urban Area

Area	Model Year	Functional Evap Checks by Calendar Year			
		1990	1996	2007	2020
Chicago	Pre-97	None	None	Cap	Cap
	1997+	None	None	Pressure/Purge	Pressure/Purge
Denver	Pre-97	None	None	Cap	Cap
	1997+	None	None	Pressure/Purge	Pressure/Purge
Houston	Pre-97	None	None	Cap	Cap
	1997+	None	None	Pressure/Purge	Pressure/Purge
Minneapolis	Pre-97	None	None	None	None
	1997+	None	None	None	None
New York City	Pre-97	None	None	Cap	Cap
	1997+	None	None	Pressure/Purge	Pressure/Purge
Philadelphia	Pre-97	None	None	Pressure	Pressure
	1997+	None	None	Pressure/Purge	Pressure/Purge
Phoenix	Pre-97	None	None	Pressure	Pressure
	1997+	None	None	Pressure/Purge	Pressure/Purge
Spokane	Pre-97	None	None	Cap	Cap
	1997+	None	None	Pressure/Purge	Pressure/Purge
St. Louis	Pre-97	None	None	Cap	Cap
	1997+	None	None	Pressure/Purge	Pressure/Purge

For pre-1997 vehicles, a gas cap only or pressure test is specified in Table 5-6, which is based on information received from EPA.[15] A gas cap test was modeled as a 40% benefit of a full pressure test. The test frequency for both the pressure and purge tests was modeled as annual or biennial, depending on the inspection frequency of the I/M program modeled for the area.

<u>Stage II Refueling Controls</u> - Consistent with the MOBILE5b model, T2ATTOX requires the user to input efficiency levels for areas that have Sage II refueling controls. Although on-board refueling vapor recovery systems will be in place on the majority of vehicles in the 2007 and 2020 runs, it is important to properly characterize Stage II efficiency in the 1990 and 1996 runs, as that is the only means of refueling control in those calendar years. Information on Stage II programs and effectiveness was provided by Sierra based on a study performed for the American Automobile Manufacturers Association in 1993.[16] Table 5-7 summarizes the Stage II program efficiencies for each city and calendar year that were used in the input files for this study.

Table 5-7
Stage II Efficiencies by City and Calendar Year
Estimated Stage II Vapor Recovery Efficiency (%)

City	Estimated Stage II Vapor Recovery Efficiency (%)			
	1990	1996	2007	2020
Chicago	0.0	85.5	85.5	85.5
Denver	0.0	0.0	0.0	0.0
Houston	0.0	76.7	85.5	85.5
Minneapolis	0.0	0.0	0.0	0.0
New York	82.6	85.5	85.5	85.5
Philadelphia	0.0	80.2	80.2	80.2
Phoenix	0.0	80.2	80.2	80.2
Spokane	0.0	0.0	0.0	0.0
St. Louis	85.5	85.5	85.5	85.5

Local Area Parameter Record and Scenario Record Inputs - The information for the parameters in the LAP record and the scenario record in each input file came from several sources. The minimum and maximum daily temperatures were taken from the Trends input files for 1990 and 1996. The 1996 temperatures were used for 2007 and 2020 as well as for 1996. Based on correspondence with EPA, it was determined that the temperatures for Winter, Spring, Summer, and Fall came from the Trends runs for January, April, July, and October for each year, respectively. The spring and summer months were evaluated for the current calendar year (e.g., 1990 for 1990, 1996 for 1996) using a July-based run; the winter evaluation was performed for the current calendar year based on a January evaluation date; and the fall evaluation was performed for the next calendar year (e.g., 1991 for 1990, 1997 for 1996) using a January evaluation date.

The RVP levels were determined from the fuel properties provided to Sierra by EPA. These RVP levels were provided for each city and year. The average speed of 19.6 mph was determined through correspondence with EPA. Finally, the operating mode fractions for VMT accumulated by non-catalyst vehicles in cold start mode, catalyst-equipped vehicles in hot-start mode, and catalyst-equipped vehicles in cold-start mode were determined from the Trends input files.

Area-Specific Toxic-TOG Curves

In addition to the standard MOBILE inputs described above, the toxic-TOG curves described in Section 4 of this report had to be generated for each fuel scenario. In total, there were 72 different fuel scenarios analyzed in this effort based on the following parameters:

- Baseline fuel for 1990, 1996, and 2007/2020;
- 40 ppm sulfur fuel for 2007/2020;
- Summer vs. winter; and
- Nine modeled urban areas.

As described in Section 4, the toxic-TOG curves for each fuel were based on relationships developed by EPA and on results from the Complex model. The fuel parameters used in this analysis were provided by EPA and are summarized in Table 5-8. (Note that the 2007 fuel properties listed in the table were also used for 2020.) From these fuel specifications, TOG and toxic emission rates were developed for normal- and high-emitting vehicles as a function of technology type, and a FORTRAN routine was written to compile the technology-based results into model-year-specific factors for use in the T2ATTOX model. A sample output from that routine is given in Appendix H for the 1990 Phoenix summertime fuel scenario.

EPA compiled the fuel parameters in Table 5-8 from a number of different sources. For the 1990 and 1996 calendar years, the fuel properties for Chicago, Denver, Minneapolis, New York, Philadelphia, Phoenix, and St. Louis came from fuel surveys conducted by the American Automobile Manufacturers Association (AAMA). The Houston fuel properties were from surveys conducted by the National Institute for Petroleum and Energy Research (NIPER). For Spokane, AAMA survey results from Billings, Montana, were used as a surrogate, and it was assumed that the Spokane oxygenated fuel requirement in 1996 was met by splash blending with ethanol.

Projections for future years were based on refinery modeling performed by EPA using the 1996 fuel properties in each area as a basis. If no new fuel programs were implemented, the baseline 2007 and 2020 fuels were assumed to be the same as 1996. For RFG areas, adjustments for the more stringent Phase II requirements (which begin in calendar year 2000) were made. To meet the Phase II RFG oxygen requirements (2.1 percent by weight), ethanol was assumed to be blended into gasoline at 6.1 volume percent, MTBE at 11.8 volume percent, or ETBE at 13.7 volume percent. Note that for older technology vehicles, ETBE-specific equations were not available, and equations developed for ethanol were used instead. This occurs only in the 2007 and 2020 summertime Chicago runs, and the impact is very slight, since older technology vehicles have been removed from the fleet by that time (except for the heavy-duty gasoline vehicle class).

Table 5-8

Fuel Parameters Used in Toxics Emissions Analysis

(Continued)

Area	RFG Area?	Year	Season	Scenario	RVP, psi	Aromatics	Olefins	Benzene %	Sulfur	E200 %	E300 %	MTBE %	ETBE %	EtOH %	Oxygen wt
Chicago	Yes	1990	Summer	Baseline	8.7	28.8	8.6	1.35	512	47.2	78.6	0.0	0.0	0.0	0.00
Chicago	Yes	1990	Winter	Baseline	13.7	23.0	9.1	1.69	450	54.4	82.6	0.0	0.0	0.0	0.00
Chicago	Yes	1996	Summer	Baseline	7.9	26.0	9.7	0.96	492	50.2	80.8	0.0	0.0	9.0	3.12
Chicago	Yes	1996	Winter	Baseline	14.0	22.4	7.8	0.80	523	58.0	83.9	0.0	0.0	9.0	3.11
Chicago	Yes	2007	Summer	Baseline	6.6	25.6	7.4	0.96	150	51.8	82.8	0.0	13.7	0.0	2.10
Chicago	Yes	2007	Winter	Baseline	14.0	21.4	6.4	0.80	150	56.8	85.9	0.0	0.0	9.0	3.10
Chicago	Yes	2007	Summer	40 ppm	6.6	26.9	4.4	0.96	40	50.0	81.5	0.0	13.7	0.0	2.10
Chicago	Yes	2007	Winter	40 ppm	14.0	19.7	3.1	0.80	40	55.9	88.2	0.0	0.0	9.0	3.10
Denver	No	1990	Summer	Baseline	8.3	24.8	12.2	1.41	375	45.1	79.4	0.0	0.0	0.0	0.00
Denver	No	1990	Winter	Baseline	12.1	19.3	12.8	1.23	272	62.0	85.5	11.6	0.0	0.0	2.06
Denver	No	1996	Summer	Baseline	8.8	27.1	8.8	1.33	296	50.1	83.1	0.0	0.0	0.0	0.00
Denver	No	1996	Winter	Baseline	13.6	21.9	9.2	0.94	350	62.1	88.1	0.0	0.0	8.4	2.90
Denver	No	2007	Summer	Baseline	8.8	27.1	8.8	1.33	296	50.1	83.1	0.0	0.0	0.0	0.00
Denver	No	2007	Winter	Baseline	13.6	21.9	9.2	0.94	350	62.1	88.1	0.0	0.0	8.4	2.90
Denver	No	2007	Summer	40 ppm	8.8	26.9	4.6	1.33	40	52.7	83.8	0.0	0.0	1.5	0.50
Denver	No	2007	Winter	40 ppm	13.8	21.8	4.7	0.94	40	61.5	88.5	0.0	0.0	8.4	2.90
Houston	Yes	1990	Summer	Baseline	8.3	30.2	10.9	1.36	375	46.7	79.4	0.5	0.0	0.0	0.10
Houston	Yes	1990	Winter	Baseline	12.8	23.0	14.4	1.22	454	52.4	80.2	0.0	0.0	0.0	0.00
Houston	Yes	1996	Summer	Baseline	7.1	27.4	13.0	0.71	261	47.8	79.8	9.8	0.0	0.0	1.74
Houston	Yes	1996	Winter	Baseline	12.8	21.1	12.8	0.70	224	59.9	83.8	7.9	0.0	0.0	1.41
Houston	Yes	2007	Summer	Baseline	6.8	27.0	9.8	0.71	145	49.3	81.8	11.8	0.0	0.0	2.10
Houston	Yes	2007	Winter	Baseline	12.8	20.2	10.5	0.70	150	58.6	85.8	11.8	0.0	0.0	2.10
Houston	Yes	2007	Summer	40 ppm	6.4	28.4	5.9	0.71	40	47.6	80.4	11.8	0.0	0.0	2.10
Houston	Yes	2007	Winter	40 ppm	12.8	18.6	5.1	0.70	40	57.7	88.1	11.8	0.0	0.0	2.10
Minneapolis	No	1990	Summer	Baseline	9.5	29.8	8.3	1.69	422	45.9	78.9	0.0	0.0	0.0	0.00
Minneapolis	No	1990	Winter	Baseline	13.2	24.9	9.3	1.86	701	56.0	81.6	0.0	0.0	0.0	0.00
Minneapolis	No	1996	Summer	Baseline	9.6	28.2	7.3	1.81	121	59.4	84.6	0.0	0.0	9.4	3.24
Minneapolis	No	1996	Winter	Baseline	14.9	23.4	5.3	1.65	70	62.3	89.1	0.0	0.0	8.0	2.77
Minneapolis	No	2007	Summer	Baseline	9.6	28.2	7.3	1.81	121	59.4	84.6	0.0	0.0	9.4	3.24
Minneapolis	No	2007	Winter	Baseline	14.9	23.4	5.3	1.65	70	62.3	89.1	0.0	0.0	8.0	2.77
Minneapolis	No	2007	Summer	40 ppm	9.6	28.0	3.9	1.81	40	62.5	85.3	0.0	0.0	9.3	3.20
Minneapolis	No	2007	Winter	40 ppm	13.8	23.2	2.7	1.65	40	61.7	89.6	0.0	0.0	8.1	2.80
New York	Yes	1990	Summer	Baseline	8.3	31.9	13.9	1.08	367	43.1	78.8	2.4	0.0	0.0	0.42
New York	Yes	1990	Winter	Baseline	13.3	26.4	16.7	1.55	274	49.5	81.8	0.0	0.0	0.0	0.00
New York	Yes	1996	Summer	Baseline	8.0	28.6	17.1	0.51	231	49.8	81.5	10.6	0.0	0.0	1.89
New York	Yes	1996	Winter	Baseline	13.2	23.3	16.6	0.47	267	57.5	85.7	14.5	0.0	0.0	2.58
New York	Yes	2007	Summer	Baseline	6.8	28.1	11.3	0.51	115	52.1	84.3	11.8	0.0	0.0	2.10
New York	Yes	2007	Winter	Baseline	13.2	22.3	13.7	0.47	150	56.2	87.7	15.0	0.0	0.0	2.70
New York	Yes	2007	Summer	40 ppm	6.6	29.6	7.8	0.51	40	49.6	82.2	11.8	0.0	0.0	2.10
New York	Yes	2007	Winter	40 ppm	13.2	20.5	6.7	0.47	40	55.3	90.1	15.0	0.0	0.0	2.70

Table 5-8

Fuel Parameters Used in Toxics Emissions Analysis

(Continued)

Area	RFG Area?	Year	Season	Scenario	RVP, psi	Aromatics	Olefins	Benzene %	Sulfur	E200 %	E300 %	MTBE %	ETBE %	EtOH %	Oxygen wt
Philadelphia	Yes	1990	Summer	Baseline	8.4	29.2	13.7	0.86	371	43.6	79.0	0.0	0.0	0.0	0.00
Philadelphia	Yes	1990	Winter	Baseline	13.9	23.5	13.2	1.63	206	50.5	82.9	0.0	0.0	0.0	0.00
Philadelphia	Yes	1996	Summer	Baseline	7.9	29.0	12.3	0.80	367	51.2	81.8	11.3	0.0	0.0	2.01
Philadelphia	Yes	1996	Winter	Baseline	13.5	25.4	10.2	0.63	337	59.3	85.9	8.8	0.0	0.0	1.58
Philadelphia	Yes	2007	Summer	Baseline	6.7	28.6	9.2	0.80	135	52.9	83.9	11.8	0.0	0.0	2.10
Philadelphia	Yes	2007	Winter	Baseline	13.5	24.3	8.4	0.63	150	58.0	88.0	11.8	0.0	0.0	2.10
Philadelphia	Yes	2007	Summer	40 ppm	6.6	30.1	5.7	0.80	40	51.0	82.5	11.8	0.0	0.0	2.10
Philadelphia	Yes	2007	Winter	40 ppm	13.5	22.4	4.1	0.62	40	57.1	90.4	11.8	0.0	0.0	2.10
Phoenix	Yes	1990	Summer	Baseline	8.1	33.0	5.9	2.15	123	41.1	78.5	0.0	0.0	0.0	0.00
Phoenix	Yes	1990	Winter	Baseline	10.9	26.4	5.6	1.88	157	56.5	82.9	11.4	0.0	0.0	2.04
Phoenix	Yes	1996	Summer	Baseline	6.8	36.1	6.8	1.07	118	45.7	76.2	0.8	0.0	0.0	0.14
Phoenix	Yes	1996	Winter	Baseline	8.7	34.3	7.1	1.40	216	50.2	82.6	0.0	0.0	10.2	3.53
Phoenix	Yes	2007	Summer	Baseline	7.0	21.9	4.1	0.55	20	49.8	84.7	11.8	0.0	0.0	2.10
Phoenix	Yes	2007	Winter	Baseline	8.7	21.9	4.1	0.69	20	55.1	84.7	15.0	0.0	0.0	2.70
Phoenix	Yes	2007	Summer	40 ppm	7.0	21.9	4.1	0.55	20	49.8	84.7	11.8	0.0	0.0	2.10
Phoenix	Yes	2007	Winter	40 ppm	8.7	21.9	4.1	0.69	20	55.1	84.7	15.0	0.0	0.0	2.70
Spokane	No	1990	Summer	Baseline	8.6	21.0	8.0	1.36	739	46.6	82.6	0.0	0.0	0.0	0.00
Spokane	No	1990	Winter	Baseline	13.1	19.2	10.3	1.58	698	51.1	84.9	0.0	0.0	0.0	0.00
Spokane	No	1996	Summer	Baseline	8.7	28.5	8.3	1.32	412	45.0	81.4	0.0	0.0	0.0	0.00
Spokane	No	1996	Winter	Baseline	14.8	18.6	6.9	0.97	350	59.8	87.1	0.0	0.0	9.3	3.20
Spokane	No	2007	Summer	Baseline	8.7	28.5	8.3	1.32	412	45.0	81.4	0.0	0.0	0.0	0.00
Spokane	No	2007	Winter	Baseline	14.8	18.5	6.9	0.96	346	60.2	87.2	0.0	0.0	10.2	3.50
Spokane	No	2007	Summer	40 ppm	8.7	28.3	4.4	1.32	40	47.3	82.0	2.8	0.0	0.0	0.50
Spokane	No	2007	Winter	40 ppm	14.8	18.4	3.5	1.00	40	59.6	87.6	0.0	0.0	10.2	3.50
St. Louis	No	1990	Summer	Baseline	8.8	28.9	8.9	1.11	372	45.2	78.9	0.0	0.0	0.0	0.00
St. Louis	No	1990	Winter	Baseline	13.2	22.0	11.4	1.71	319	54.0	82.7	0.0	0.0	0.0	0.00
St. Louis	No	1996	Summer	Baseline	6.8	29.9	12.0	0.70	492	39.0	78.8	0.0	0.0	0.0	0.00
St. Louis	No	1996	Winter	Baseline	13.6	23.8	11.4	0.89	535	52.7	82.6	0.0	0.0	0.0	0.00
St. Louis	Yes	2007	Summer	Baseline	6.4	29.4	10.8	0.69	145	44.2	83.5	0.0	13.7	0.0	2.10
St. Louis	Yes	2007	Winter	Baseline	13.6	22.4	9.9	0.89	150	52.5	84.7	0.0	0.0	6.1	2.10
St. Louis	Yes	2007	Summer	40 ppm	6.4	29.7	6.4	0.69	40	43.2	83.5	0.0	13.7	0.0	2.10
St. Louis	Yes	2007	Winter	40 ppm	13.8	23.6	5.8	0.89	40	52.2	83.0	0.0	0.0	6.1	2.10

Area-Specific Evaporative Benzene and MTBE Fractions

The methodology described in Section 4 to determine benzene and MTBE evaporative fractions was applied to the fuel data in Table 5-8. Because the same fractions are applied to all technologies, the evaporative input file for the T2ATTOX runs consists of only two lines of data – one reflecting benzene fractions and one reflecting MTBE fractions. These fractions are applied to the TOG emissions from the appropriate evaporative process (e.g., hot soak, diurnal, etc.). A sample evaporative fraction input file for 1990 Phoenix summertime fuel is presented in Appendix I.

Input File Development

All of the area-specific inputs (the MOBILE5 flags, registration fractions, VMT mix, I/M program parameters, etc.) were entered into a Microsoft Access database. Several different tables were created in the database, one for each group of input parameters (e.g., one table for input flags, another for I/M parameters). Once all values had been entered, each of the inputs was checked for accuracy.

Input File "Builder" Routine - In order to transfer the information from the Access table to the ASCII T2ATTOX input files, Radian developed an input file "builder" routine in a Visual Basic module in Access. This Visual Basic module read in the information from each table, created an input file for each city, year, season, and control scenario, and wrote the relevant information from the Access tables into the correct format in the input file. The automated process of developing the input files reduced the number of times that parameters needed to be typed into an ASCII file and significantly reduced the risk of transcription errors. Appendix J shows an example input file (a selected file for Phoenix) that was developed by the input file "builder" routine.

Modeling Runs - Once the input files were built for each city, year, season, and control scenario, the modified T2ATTOX model was run for each file. An output file from the model is contained in Appendix K, which shows the results based on the Phoenix input file presented in Appendix J. A FORTRAN program was developed to process the output files and condense the results into one large data file for later computation of toxics exposure described in the next section of this report.

PART5 Input Files

The PART5 input files were developed using many of the same sources that were used for the Toxics input files. The registration fractions used for the T2ATTOX model were also used for the PART5 input files. The registration fractions for HDDVs were used for each of the heavy-duty vehicle classes in PART5.

The VMT mixes from the Toxics inputs were also used for the PART5 input files. The HDDV VMT fraction was broken down into the five VMT fractions (2BHDDV, LHDDV, MHDDV, HHDDV, and buses) using the ratios that were included in the examples in the PART5 User's Guide (i.e., standard model output). For example, the 1996 VMT fraction for HDDV was 0.070. This number was broken down into five VMT fractions based on the ratios of 15.8%, 1.6%, 22.2%, 54.0%, and 6.4% for 2BHDDV, LHDDV, MHDDV, HHDDV, and buses, respectively. The resulting VMT fractions were 0.01, 0.001, 0.014, 0.034, and 0.004 for each of these vehicle classes.

Other inputs for the PART5 files, such as percent of paved and unpaved silt, number of precipitation days, and particle size cutoff, were taken from the Trends PART5 input files.

Results from the PART5 runs were also summarized into a single output file for later use in the exposure and risk analyses.

###

6. MOTOR VEHICLE TOXICS EMISSIONS ESTIMATES

Using the methodologies and models described above, estimates of on-road motor vehicle toxics emission rates were prepared for benzene, acetaldehyde, formaldehyde, 1,3-butadiene, MTBE, and Diesel PM. As described in the preceding section, emission rates were generated for each quarter and for each vehicle class. In addition, annual average estimates were prepared by taking the mean of the quarterly results. Consistent with the requirements of this study, toxics emissions estimates were prepared for (a) calendar years 1990, 1996, 2007, and 2020; (b) baseline emission factors and fuels (for all calendar years); (c) three control scenarios (for 2007 and 2020); and (d) nine urban areas.

Fleet-average emission results (i.e., all vehicle classes combined) are given in Tables 6-1 through 6-6 for benzene, acetaldehyde, formaldehyde, 1,3-butadiene, MTBE, and Diesel PM, respectively. Because of the voluminous nature of these estimates, results are presented only for Chicago and Phoenix; the complete set of toxics emission rates calculated in this study is contained in Volume II of this report. Recall that the control scenarios consisted of:

- Scenario 1 - baseline emission factors (which include a national LEV program) with a national 40 ppm gasoline sulfur limit;

- Scenario 2 - Scenario 1 with more stringent NMHC standards for 2004 and later model year light-duty cars and trucks; and

- Scenario 3 - Scenario 2 with increased Diesel light-duty truck penetration beginning in 2004, with 50% of new light-truck sales being Diesel in 2007.

Reviewing the fleet-average toxics emission factors in Tables 6-1 to 6-6, the following observations can be made:

- Significant reductions in fleet-average toxics emissions are observed between 1990 and 2020 with no further vehicle or fuel controls. This is a result of fleet-turnover resulting in full implementation of the federal emission control regulations currently on the books.

- Toxic emissions in Chicago are typically at a minimum in summer. This is a result of elevated exhaust hydrocarbon emissions (which are directly related to most toxics emissions rates) in winter and fall due to cold temperature. However, the

Table 6-1
On-Road Motor Vehicle Benzene Emission Rates for Chicago and Phoenix
(Units: mg/mi)

Area	Quarter	Scenario	1990 CO Emissions	Calendar Year 1990	1996	2007	2020
Chicago	Winter	Base	43.8	144.1	74.6	33.6	20.2
		Sc#1	43.8	---	---	30.5	18.1
		Sc#2	43.8	---	---	29.0	13.1
		Sc#3	43.8	---	---	25.6	10.1
	Spring	Base	35.8	117.2	49.9	22.0	13.5
		Sc#1	35.8	---	---	21.8	12.9
		Sc#2	35.8	---	---	20.8	9.6
		Sc#3	35.8	---	---	18.6	7.7
	Summer	Base	33.2	101.2	40.7	18.1	11.0
		Sc#1	33.2	---	---	17.9	10.6
		Sc#2	33.2	---	---	17.2	8.1
		Sc#3	33.2	---	---	15.6	6.7
	Fall	Base	36.3	116.1	48.1	23.3	15.0
		Sc#1	36.3	---	---	21.7	13.8
		Sc#2	36.3	---	---	20.8	10.9
		Sc#3	36.3	---	---	18.7	8.8
	Ann Ave	Base	37.3	119.7	53.3	24.2	14.9
		Sc#1	37.3	---	---	23.0	13.8
		Sc#2	37.3	---	---	21.9	10.4
		Sc#3	37.3	---	---	19.6	8.3
Phoenix	Winter	Base	29.3	118.2	76.6	19.8	11.6
		Sc#1	29.3	---	---	19.8	11.6
		Sc#2	29.3	---	---	19.0	8.7
		Sc#3	29.3	---	---	17.2	7.0
	Spring	Base	31.4	130.7	63.2	13.7	8.4
		Sc#1	31.4	---	---	13.7	8.4
		Sc#2	31.4	---	---	13.2	6.5
		Sc#3	31.4	---	---	12.1	5.4
	Summer	Base	42.3	166.1	78.0	16.6	10.0
		Sc#1	42.3	---	---	16.6	10.0
		Sc#2	42.3	---	---	16.0	7.8
		Sc#3	42.3	---	---	14.5	6.4
	Fall	Base	31.6	122.7	67.2	16.6	10.5
		Sc#1	31.6	---	---	16.6	10.5
		Sc#2	31.6	---	---	15.8	7.9
		Sc#3	31.6	---	---	14.3	6.5
	Ann Ave	Base	33.7	134.4	71.2	16.7	10.1
		Sc#1	33.7	---	---	16.7	10.1
		Sc#2	33.7	---	---	16.0	7.7
		Sc#3	33.7	---	---	14.6	6.4

Table 6-2
On-Road Motor Vehicle Acetaldehyde Emission Rates
for Chicago and Phoenix
(Units: mg/mi)

Area	Quarter	Scenario	1990 CO Emissions	Calendar Year			
				1990	1996	2007	2020
Chicago	Winter	Base	43.8	21.5	25.4	11.1	6.0
		Sc#1	43.8	---	---	10.7	5.7
		Sc#2	43.8	---	---	10.3	4.5
		Sc#3	43.8	---	---	9.5	4.0
	Spring	Base	35.8	18.1	17.0	6.6	4.0
		Sc#1	35.8	---	---	6.5	3.8
		Sc#2	35.8	---	---	6.3	3.2
		Sc#3	35.8	---	---	6.1	3.0
	Summer	Base	33.2	15.7	14.0	5.5	3.4
		Sc#1	33.2	---	---	5.4	3.3
		Sc#2	33.2	---	---	5.3	2.8
		Sc#3	33.2	---	---	5.2	2.7
	Fall	Base	36.3	16.2	14.8	6.3	4.1
		Sc#1	36.3	---	---	6.1	3.9
		Sc#2	36.3	---	---	5.9	3.2
		Sc#3	36.3	---	---	5.7	3.1
	Ann Ave	Base	37.3	17.9	17.8	7.4	4.4
		Sc#1	37.3	---	---	7.2	4.2
		Sc#2	37.3	---	---	6.9	3.4
		Sc#3	37.3	---	---	6.6	3.2
Phoenix	Winter	Base	29.3	17.9	20.1	4.2	2.5
		Sc#1	29.3	---	---	4.2	2.5
		Sc#2	29.3	---	---	4.2	2.2
		Sc#3	29.3	---	---	4.3	2.3
	Spring	Base	31.4	15.2	9.6	3.6	2.3
		Sc#1	31.4	---	---	3.6	2.3
		Sc#2	31.4	---	---	3.5	2.0
		Sc#3	31.4	---	---	3.7	2.2
	Summer	Base	42.3	16.9	10.6	3.8	2.4
		Sc#1	42.3	---	---	3.8	2.4
		Sc#2	42.3	---	---	3.7	2.1
		Sc#3	42.3	---	---	3.9	2.2
	Fall	Base	31.6	15.3	16.4	3.5	2.3
		Sc#1	31.6	---	---	3.5	2.3
		Sc#2	31.6	---	---	3.4	2.0
		Sc#3	31.6	---	---	3.5	2.2
	Ann Ave	Base	33.7	16.3	14.2	3.8	2.4
		Sc#1	33.7	---	---	3.8	2.4
		Sc#2	33.7	---	---	3.7	2.1
		Sc#3	33.7	---	---	3.9	2.2

Table 6-3
On-Road Motor Vehicle Formaldehyde Emission Rates
for Chicago and Phoenix
(Units: mg/mi)

Area	Quarter	Scenario	1990 CO Emissions	Calendar Year 1990	1996	2007	2020
Chicago	Winter	Base	43.8	66.8	39.8	18.1	10.1
		Sc#1	43.8	---	---	18.0	10.1
		Sc#2	43.8	---	---	17.5	8.3
		Sc#3	43.8	---	---	17.2	8.1
	Spring	Base	35.8	55.4	28.2	12.4	7.6
		Sc#1	35.8	---	---	12.4	7.6
		Sc#2	35.8	---	---	12.0	6.5
		Sc#3	35.8	---	---	12.4	6.7
	Summer	Base	33.2	48.4	24.4	10.7	6.7
		Sc#1	33.2	---	---	10.7	6.7
		Sc#2	33.2	---	---	10.5	5.9
		Sc#3	33.2	---	---	11.1	6.3
	Fall	Base	36.3	50.1	25.2	11.3	7.5
		Sc#1	36.3	---	---	11.3	7.4
		Sc#2	36.3	---	---	11.0	6.4
		Sc#3	36.3	---	---	11.3	6.7
	Ann Ave	Base	37.3	55.2	29.4	13.1	8.0
		Sc#1	37.3	---	---	13.1	8.0
		Sc#2	37.3	---	---	12.8	6.8
		Sc#3	37.3	---	---	13.0	6.9
Phoenix	Winter	Base	29.3	71.1	35.5	15.3	8.2
		Sc#1	29.3	---	---	15.3	8.2
		Sc#2	29.3	---	---	15.0	7.1
		Sc#3	29.3	---	---	15.1	7.3
	Spring	Base	31.4	49.3	30.1	12.1	7.2
		Sc#1	31.4	---	---	12.1	7.2
		Sc#2	31.4	---	---	11.9	6.3
		Sc#3	31.4	---	---	12.3	6.7
	Summer	Base	42.3	54.8	33.5	13.1	7.7
		Sc#1	42.3	---	---	13.1	7.7
		Sc#2	42.3	---	---	12.8	6.6
		Sc#3	42.3	---	---	13.1	6.9
	Fall	Base	31.6	60.1	29.2	11.9	7.6
		Sc#1	31.6	---	---	11.9	7.6
		Sc#2	31.6	---	---	11.6	6.6
		Sc#3	31.6	---	---	11.9	6.9
	Ann Ave	Base	33.7	58.9	32.0	13.1	7.7
		Sc#1	33.7	---	---	13.1	7.7
		Sc#2	33.7	---	---	12.8	6.7
		Sc#3	33.7	---	---	13.1	6.9

Table 6-4
On-Road Motor Vehicle 1,3-Butadiene Emission Rates for Chicago and Phoenix (Units: mg/mi)

Area	Quarter	Scenario	1990 CO Emissions	Calendar Year 1990	1996	2007	2020
Chicago	Winter	Base	43.8	20.4	10.0	4.2	2.9
		Sc#1	43.8	---	---	3.8	2.5
		Sc#2	43.8	---	---	3.7	2.0
		Sc#3	43.8	---	---	3.6	1.8
	Spring	Base	35.8	16.9	7.3	2.9	2.1
		Sc#1	35.8	---	---	2.7	1.9
		Sc#2	35.8	---	---	2.6	1.6
		Sc#3	35.8	---	---	2.6	1.4
	Summer	Base	33.2	14.0	5.8	2.3	1.7
		Sc#1	33.2	---	---	2.2	1.6
		Sc#2	33.2	---	---	2.1	1.3
		Sc#3	33.2	---	---	2.2	1.2
	Fall	Base	36.3	14.5	5.7	2.4	1.8
		Sc#1	36.3	---	---	2.2	1.6
		Sc#2	36.3	---	---	2.1	1.3
		Sc#3	36.3	---	---	2.2	1.3
	Ann Ave	Base	37.3	16.5	7.2	3.0	2.1
		Sc#1	37.3	---	---	2.7	1.9
		Sc#2	37.3	---	---	2.6	1.6
		Sc#3	37.3	---	---	2.6	1.4
Phoenix	Winter	Base	29.3	14.3	8.0	2.5	1.7
		Sc#1	29.3	---	---	2.5	1.7
		Sc#2	29.3	---	---	2.4	1.4
		Sc#3	29.3	---	---	2.5	1.3
	Spring	Base	31.4	13.6	7.6	2.1	1.5
		Sc#1	31.4	---	---	2.1	1.5
		Sc#2	31.4	---	---	2.0	1.3
		Sc#3	31.4	---	---	2.1	1.2
	Summer	Base	42.3	15.4	8.7	2.3	1.7
		Sc#1	42.3	---	---	2.3	1.7
		Sc#2	42.3	---	---	2.3	1.4
		Sc#3	42.3	---	---	2.3	1.3
	Fall	Base	31.6	11.6	6.3	2.0	1.5
		Sc#1	31.6	---	---	2.0	1.5
		Sc#2	31.6	---	---	1.9	1.2
		Sc#3	31.6	---	---	2.0	1.2
	Ann Ave	Base	33.7	13.7	7.7	2.2	1.6
		Sc#1	33.7	---	---	2.2	1.6
		Sc#2	33.7	---	---	2.2	1.3
		Sc#3	33.7	---	---	2.2	1.3

Table 6-5
On-Road Motor Vehicle MTBE Emission Rates
for Chicago and Phoenix
(Units: mg/mi)

			1990 CO	Calendar Year			
Area	Quarter	Scenario	Emissions	1990	1996	2007	2020
Chicago	Winter	Base	43.8	0.0	0.0	0.0	0.0
		Sc#1	43.8	---	---	0.0	0.0
		Sc#2	43.8	---	---	0.0	0.0
		Sc#3	43.8	---	---	0.0	0.0
	Spring	Base	35.8	0.0	0.0	0.0	0.0
		Sc#1	35.8	---	---	0.0	0.0
		Sc#2	35.8	---	---	0.0	0.0
		Sc#3	35.8	---	---	0.0	0.0
	Summer	Base	33.2	0.0	0.0	0.0	0.0
		Sc#1	33.2	---	---	0.0	0.0
		Sc#2	33.2	---	---	0.0	0.0
		Sc#3	33.2	---	---	0.0	0.0
	Fall	Base	36.3	0.0	0.0	0.0	0.0
		Sc#1	36.3	---	---	0.0	0.0
		Sc#2	36.3	---	---	0.0	0.0
		Sc#3	36.3	---	---	0.0	0.0
	Ann Ave	Base	37.3	0.0	0.0	0.0	0.0
		Sc#1	37.3	---	---	0.0	0.0
		Sc#2	37.3	---	---	0.0	0.0
		Sc#3	37.3	---	---	0.0	0.0
Phoenix	Winter	Base	29.3	149.0	0.0	40.6	23.4
		Sc#1	29.3	---	---	40.6	23.4
		Sc#2	29.3	---	---	40.3	22.0
		Sc#3	29.3	---	---	34.6	16.6
	Spring	Base	31.4	0.0	5.9	33.9	19.3
		Sc#1	31.4	---	---	33.9	19.3
		Sc#2	31.4	---	---	33.6	18.3
		Sc#3	31.4	---	---	29.3	14.2
	Summer	Base	42.3	0.0	10.1	61.8	33.7
		Sc#1	42.3	---	---	61.8	33.7
		Sc#2	42.3	---	---	61.5	32.7
		Sc#3	42.3	---	---	53.6	25.1
	Fall	Base	31.6	261.8	0.0	55.7	32.6
		Sc#1	31.6	---	---	55.7	32.6
		Sc#2	31.6	---	---	55.4	31.4
		Sc#3	31.6	---	---	48.5	24.5
	Ann Ave	Base	33.7	102.7	4.0	48.0	27.3
		Sc#1	33.7	---	---	48.0	27.3
		Sc#2	33.7	---	---	47.7	26.1
		Sc#3	33.7	---	---	41.5	20.1

Table 6-6
On-Road Motor Vehicle Diesel PM Emission Rates for Chicago and Phoenix (Units: mg/mi)

Area	Quarter	Scenario	1990 CO Emissions	Calendar Year 1990	1996	2007	2020
Chicago	Winter	Base	43.8	93.6	55.3	23.8	17.4
		Sc#1	43.8	---	---	23.8	17.4
		Sc#2	43.8	---	---	23.8	17.4
		Sc#3	43.8	---	---	39.7	41.3
	Spring	Base	35.8	94.6	55.3	23.8	17.4
		Sc#1	35.8	---	---	23.8	17.4
		Sc#2	35.8	---	---	23.8	17.4
		Sc#3	35.8	---	---	39.7	41.3
	Summer	Base	33.2	94.6	55.3	23.8	17.4
		Sc#1	33.2	---	---	23.8	17.4
		Sc#2	33.2	---	---	23.8	17.4
		Sc#3	33.2	---	---	39.7	41.3
	Fall	Base	36.3	91.3	48.5	22.0	17.4
		Sc#1	36.3	---	---	22.0	17.4
		Sc#2	36.3	---	---	22.0	17.4
		Sc#3	36.3	---	---	35.8	41.3
	Ann Ave	Base	37.3	93.5	53.6	23.4	17.4
		Sc#1	37.3	---	---	23.4	17.4
		Sc#2	37.3	---	---	23.4	17.4
		Sc#3	37.3	---	---	38.7	41.3
Phoenix	Winter	Base	29.3	92.7	62.7	23.8	17.4
		Sc#1	29.3	---	---	23.8	17.4
		Sc#2	29.3	---	---	23.8	17.4
		Sc#3	29.3	---	---	39.7	41.3
	Spring	Base	31.4	94.0	62.7	23.8	17.4
		Sc#1	31.4	---	---	23.8	17.4
		Sc#2	31.4	---	---	23.8	17.4
		Sc#3	31.4	---	---	39.7	41.3
	Summer	Base	42.3	94.0	62.7	23.8	17.4
		Sc#1	42.3	---	---	23.8	17.4
		Sc#2	42.3	---	---	23.8	17.4
		Sc#3	42.3	---	---	39.7	41.3
	Fall	Base	31.6	90.6	56.5	22.0	17.4
		Sc#1	31.6	---	---	22.0	17.4
		Sc#2	31.6	---	---	22.0	17.4
		Sc#3	31.6	---	---	35.8	41.3
	Ann Ave	Base	33.7	92.9	61.2	23.4	17.4
		Sc#1	33.7	---	---	23.4	17.4
		Sc#2	33.7	---	---	23.4	17.4
		Sc#3	33.7	---	---	38.7	41.3

opposite is true of the Phoenix runs. Because the fall and winter temperatures are relatively mild in Phoenix, large increases in exhaust hydrocarbon emissions as a result of cold temperature are not observed. In fact, the very high summer temperatures result in both increased evaporative emissions (causing increases in benzene and MTBE, when present) and increased exhaust emissions (as a result of increased vapor from canister purge).

- Implementation of Scenario 1 has no impact on the Phoenix runs. That is because it was assumed that Phoenix would continue to use CARB "Cleaner Burning Gasoline" (CBG), which already has sulfur levels below 40 ppm on average.

- For the Chicago runs, Scenario 1 has the largest impact on benzene and 1,3-butadiene emissions. Aldehyde emissions are less affected under this scenario.

- Because it is assumed that gasoline dispensed in Chicago will use either ETBE or ethanol as an oxygenate, MTBE emission rates are zero for all scenarios.

- Moderate reductions are observed with Scenario 2 in 2007. However, by 2020 fleet-turnover impacts result in fleet-average toxic emission reductions on the order of 15% to 25%.

- Implementation of Scenario 3 results in reductions in benzene, acetaldehyde, 1,3-butadiene, and MTBE (where used). However, formaldehyde emissions show a slight increase. Obviously, Diesel PM emissions increase substantially under this scenario.

###

7. TOXICS EXPOSURE ESTIMATES

Using the motor vehicle toxics emission rates described in the previous section of this report, CO exposure estimates prepared with the HAPEM-MS model, and the 1990 CO emission rates generated for each of the study areas, exposure estimates were calculated for all study areas and scenarios evaluated in this effort. As described in Section 2, the approach used to estimate toxics exposure was based on the following formula:

$$TOX_{Exposure(\mu g/m3)} = [CO_{Exposure(\mu g/m3)}/CO_{EF(g/mi)}]_{1990} \times TOX_{EF(g/mi)}$$

where TOX reflects one of the six toxic pollutants considered in this study. Because some of the toxic pollutants evaluated in this study (e.g., 1,3-butadiene) have a different photochemical reactivity than CO, the exposure concentrations were adjusted to account for atmospheric transformation. In addition, because the CO ratios are based on the 1990 calendar year, an adjustment was made to account for the increase in VMT relative to 1990.

Details of the calculations performed to generate exposure estimates for this study are described below. Estimates were prepared for three specific demographic groups: outdoor workers, children 0 to 17 years of age, and the total population. These groups were selected because outdoor workers are generally the highest exposed demographic group, children 0 to 17 represent a very sensitive demographic group, and the total population gives an average exposure estimate.

1990 CO Exposure Estimates

The calendar year 1990 CO exposure estimates *related to on-road motor vehicles* were provided to Sierra by EPA. Those estimates, which are summarized in Table 7-1, were based on a recent study performed by Mantech Environmental Technology under contract to EPA.[17] That study used the Hazardous Air Pollutant Exposure Model (HAPEM) to generate estimates of human exposure to ambient CO. The HAPEM model links human activity patterns with ambient CO concentration to arrive at average exposure estimates for 22 different demographic groups (e.g., outdoor workers, children 0 to 17, working men 18 to 44, women 65+, etc.) and for the total population. The model simulates the movement of individuals between home and work and through a number of different microenviroments (37 in total). The CO concentration in each microenvironment is determined by multiplying ambient concentration by a microenvironmental factor. For example, a factor of 0.38 is used for time spent in an office building, while a factor of 2.11 is used for time spent in a shopping mall.

Table 7-1
1990 On-Road Motor Vehicle CO Exposure Estimates (μg/m^3)

Urban Area	Demo Group	Quarter 1	Quarter 2	Quarter 3	Quarter 4
Chicago	Outdoor Workers	455	344	317	378
	Children 0-17	366	286	261	309
	Total Population	375	290	261	316
Denver	Outdoor Workers	696	358	364	628
	Children 0-17	556	289	294	508
	Total Population	569	295	297	518
Houston	Outdoor Workers	305	235	388	429
	Children 0-17	258	193	322	370
	Total Population	262	197	322	373
Minneapolis	Outdoor Workers	872	593	538	681
	Children 0-17	698	489	442	550
	Total Population	724	497	446	566
New York	Outdoor Workers	947	771	662	751
	Children 0-17	764	637	548	612
	Total Population	793	658	561	636
Philadelphia	Outdoor Workers	608	343	337	444
	Children 0-17	508	297	284	379
	Total Population	515	295	280	381
Phoenix	Outdoor Workers	685	360	449	757
	Children 0-17	591	308	378	649
	Total Population	596	310	374	654
Spokane	Outdoor Workers	795	458	713	745
	Children 0-17	636	367	568	592
	Total Population	651	370	566	606
St. Louis	Outdoor Workers	374	245	197	313
	Children 0-17	302	204	166	268
	Total Population	309	205	165	269

With the CO exposure estimates generated by HAPEM model, EPA determined the fraction of exposure that was a result of on-road motor vehicles. This was accomplished by scaling the annual and quarterly exposure estimates prepared by Mantech (which reflect exposure to total ambient CO) by the fraction of the 1990 CO emissions inventory that was from on-road motor vehicles. The inventory estimates used for this purpose were prepared by E.H. Pechan under contract to EPA.[18] A spreadsheet with the exposure results was provided to Sierra; the results were then summarized in an ASCII file that was used as an input to a FORTRAN routine that compiled the exposure data, CO emissions data, and the toxics emissions data to calculate toxics exposure and risk for each of the urban areas and scenarios included in this study. The exposure estimates given in Table 7-1 reflect the adjustment to account only for on-road motor vehicles.

CO Emissions Estimates

As outlined above, the calendar year 1990 fleet-average CO emission rate is used in the toxics exposure calculation. These CO estimates were prepared with a modified version of the T2ATTOX model, which is described in Section 3 of this report. (Changes to the current MOBILE5b inputs were made to account for revised base emission rates, off-cycle effects, and revised oxygenated fuels effects.) A summary of the calendar year 1990 fleet-average CO emission rates calculated for each area and quarter is given in Table 7-2. Note that only baseline numbers were calculated, since no alternative control programs were assumed in the 1990 runs.

Table 7-2
1990 On-Road Motor Vehicle CO Emissions Estimates by Urban Area and Quarter (g/mi)

Urban Area	Quarter			
	1	2	3	4
Chicago	43.8	35.8	33.2	36.3
Denver	55.4	55.4	50.0	46.4
Houston	46.6	36.3	44.8	40.8
Minneapolis	61.8	47.8	41.5	47.3
New York	43.1	35.1	33.4	36.0
Philadelphia	54.6	44.7	43.4	45.4
Phoenix	29.3	31.4	42.3	31.6
Spokane	45.2	38.8	33.5	40.4
St. Louis	44.1	36.2	36.6	37.9

Several points can be made in reference to Table 7-2:

- In general, CO emissions in the winter (i.e., quarter 1) are higher than in the other seasons. This occurs because temperatures are lower, which results in elevated CO emissions from gasoline-fueled vehicles (primarily due to cold-start increases).

- The one area where CO emissions are lower in winter than in the other seasons is Phoenix. That is because Phoenix had a winter oxygenated fuels program in 1990, which resulted in CO emissions decreases. In addition, the winter ambient temperatures in Phoenix are relatively mild (44° to 67°F diurnal temperature pattern), which mitigates the cold-start effects observed in some of the other communities. Because Phoenix is very hot in the summer (83° to 105°F diurnal temperature pattern), the impact of air conditioning usage is maximized in the summer run (quarter 3), resulting in elevated CO emission rates in the summer.

- Denver also had an oxygenated fuels program in 1990, which results in the winter CO emission rates being the same as in the spring (quarter 2) run, even though the temperature was lower in the winter run.

- Because the fall runs (quarter 4) were performed using a January 1991 evaluation date in the MOBILE input files, those results reflect an additional year of fleet turnover relative to the winter runs (which were based on a January 1990 evaluation date). The spring and summer runs assumed a July 1990 evaluation date, reflecting six months of additional fleet turnover relative to the winter runs.

Reactivity and VMT Adjustments

As outlined previously, unadjusted toxic exposure estimates can be determined from the following formula:

$$TOX_{Exposure(\mu g/m3)} = [CO_{Exposure(\mu g/m3)}/CO_{EF(g/mi)}]_{1990} \times TOX_{EF(g/mi)}$$

However, because some of the toxic pollutants evaluated in this study (i.e., formaldehyde, acetaldehyde, and 1,3-butadiene) have a different photochemical reactivity than CO, the exposure concentrations must be adjusted to account for atmospheric transformation. In addition, because the CO ratios are based on the 1990 calendar year, an adjustment must be made to account for the increase in VMT relative to 1990, i.e.,

$$TOX_{Exposure\text{-}Adj\ (\mu g/m3)} = TOX_{Exposure\text{-}Unadj\ (\mu g/m3)} \times Reactivity_{Adj} \times VMT_{Adj}$$

The specific adjustments to account for reactivity and VMT are described below.

Reactivity Adjustments - The reactivity adjustments used in this effort were provided to Sierra by EPA staff,[19] and are summarized as follows:

- *1,3-Butadiene* - Seasonal reactivity adjustments were estimated by EPA. These multiplicative factors are 0.44 for summer, 0.70 for spring and fall, and 0.96 for winter.

- *Benzene, MTBE, and Diesel PM* - These were assumed to be inert for the modeling performed in this study.

- *Formaldehyde and Acetaldehyde* - There is strong evidence to suggest that these species undergo substantive atmospheric transformation, both in terms of decay of primary (i.e., tailpipe) emissions and in the formation of secondary formaldehyde and acetaldehyde. However, because of the complexities involved in quantifying that effect, it was not addressed in this study. Thus, the calculations performed to generate the exposure estimates presented below treat these species as if they were inert. If the formaldehyde and acetaldehyde exposure estimates generated in this study are used in ensuing risk assessments, some accounting for atmospheric transformation would be warranted.

VMT Adjustments - As discussed in Section 6, future-year on-road motor vehicle toxics emissions estimates are expected to decline significantly as a result of fleet turnover effects (i.e., older, high-emitting vehicles are replaced by newer technology vehicles with more durable emissions control systems), improved I/M program designs, and the use of cleaner fuels. However, those reductions cannot be used directly to assess corresponding reductions in ambient concentrations. That is because growth in VMT will partially offset the gains made in per-vehicle (or per-mile) reductions. That being the case, the toxics exposure estimates for future years need to be adjusted to account for VMT increases relative to the 1990 base year used to estimate CO exposure.

The VMT projections for each of the urban areas evaluated in this study were based on an evaluation of the "Trends" database performed by an EPA contractor.[20] The results of this analysis are presented in Table 7-3. Note that Sierra was provided VMT forecasts only for 1990, 1996, 2007, and 2010. The 2020 values shown in Table 7-3 were extrapolated from the 2010 numbers by applying the annualized growth rate observed between 2007 and 2010. For example, the estimated Chicago VMT in 2007 is 74,646,000 miles and in 2010 it is 78,428,000 miles. Thus the annualized growth over those three years is:

$$\text{Annual VMT Growth} = (78{,}428/74{,}646)^{1/3} - 1.0 = 0.0166$$

or 1.66%. This value was used in conjunction with the 2010 VMT forecast to arrive at a 2020 estimate:

$$VMT_{CH\text{ - }2020} = 78{,}428{,}000 \times (1.0166)^{10} = 92.5 \text{ million miles}$$

Using the VMT estimates shown in Table 7-3, VMT growth rate adjustment factors were generated for each urban area. These results are given in Table 7-4.

Table 7-3
VMT Forecasts by Urban Area
(1000s of Miles)

Urban Area	1990	1996	2007	2010	2020
Chicago	49,032	62,408	74,646	78,428	92,474
Denver	14,289	20,189	26,636	28,444	35,406
Houston	24,400	40,684	52,550	55,819	68,256
Minneapolis	17,798	22,506	28,350	29,958	36,008
New York	92,323	103,195	117,422	122,258	139,863
Philadelphia	36,612	43,286	52,169	54,711	64,114
Phoenix	18,762	25,017	33,295	35,788	45,531
Spokane	3,447	4,105	5,146	5,446	6,581
St. Louis	18,037	27,903	32,383	33,985	39,919

Table 7-4
VMT Adjustment Factors by Urban Area Relative to 1990

Urban Area	1990	1996	2007	2020
Chicago	1.000	1.273	1.522	1.886
Denver	1.000	1.413	1.864	2.478
Houston	1.000	1.667	2.154	2.797
Minneapolis	1.000	1.265	1.593	2.023
New York	1.000	1.118	1.272	1.515
Philadelphia	1.000	1.182	1.425	1.751
Phoenix	1.000	1.333	1.775	2.427
Spokane	1.000	1.191	1.493	1.909
St. Louis	1.000	1.547	1.795	2.213

Modeled Urban Area Toxics Exposure Estimates

Using the methodology described above, toxics exposure estimates were prepared for each of the nine urban areas included in this study. These estimates were generated for calendar years 1990, 1996, 2007, and 2020, and estimates were prepared for each quarter as well as on an annual average basis. Finally, separate estimates were calculated for the three demographic groups discussed above, and the 2007 and 2020 runs include baseline control assumptions and the three control scenarios. Obviously, presenting the entire set of results within the text of this report is not viable. Only the highlights are discussed below; complete results by urban area and vehicle class can be found in Volume II of this report.

FORTRAN Model - Because of the large number of scenarios modeled in this effort, the compilation of toxics emissions data, CO emissions data, and CO exposure estimates was performed within a FORTRAN routine. As described later in this report, this also facilitated the calculation of national exposure estimates as well as risk analysis (i.e., estimating the number of cancer incidences per million people and the overall number of cancer cases as a result of the various scenarios modeled in this study).

As an example of the calculation, the baseline Chicago 1996 winter benzene exposure for the total population demographic group was estimated as follows. Variables in the calculation are listed below.

$CO_{\text{Exposure - Win 90}}$	$= 375\ \mu g/m^3$	(from Table 7-1)
$CO_{\text{Emissions-Win 90}}$	$= 43.8$ g/mi	(from Table 7-2)
$\text{Benzene}_{\text{Emissions-Win 96}}$	$= 67.76$ mg/mi	(See Section 6)
VMT Growth_{1996}	$= 1.273$	(from Table 7-4)

Using the equation described above, the winter 1996 Chicago benzene exposure in this case was then calculated as:

$$\text{Bnz}_{\text{Exposure-Win 96}} = (375\ \mu g/m^3 / 43.8\ g/mi) \times (67.76\ mg/mi / 1000) \times 1.273$$
$$\text{Bnz}_{\text{Exposure-Win 96}} = 0.739\ \mu g/m^3$$

Note that no transformation term was included in this calculation as benzene was assumed to be inert for the purposes of the exposure estimates. The same methodology was used to calculate benzene exposure for the remaining seasons, resulting in the following estimates:

$$\text{Bnz}_{\text{Exposure-Spr 96}} = 0.512\ \mu g/m^3$$
$$\text{Bnz}_{\text{Exposure-Sum 96}} = 0.405\ \mu g/m^3$$
$$\text{Bnz}_{\text{Exposure-Fall 96}} = 0.491\ \mu g/m^3$$

An annual average exposure estimate was calculated as the arithmetic mean of the four seasonal values. In this case, the annual average Chicago benzene exposure was calculated to be 0.537 $\mu g/m^3$.

At the request of the work assignment manager, exposure estimates were also generated by vehicle class. This was accomplished by multiplying the overall on-road motor vehicle exposure (calculated above) by the fractional contribution of each vehicle class to the fleet-average emission rate. For example, the LDGV (i.e., passenger car) benzene emission rate in the winter 1996 run was 64.24 mg/mi, with that vehicle class contributing 55.0% of overall VMT. Thus, this vehicle class contributed:

$$\text{Bnz Fraction}_{LDGV} = (64.24 \text{ mg/mi} \times 0.550)/67.76 \text{ mg/mi} = 0.521$$

where 67.76 mg/mi is the fleet-average emission rate. Using this value in conjunction with the overall 1996 Chicago winter benzene on-road motor vehicle exposure, the exposure as a result of the LDGV class was calculated as:

$$\text{Bnz}_{\text{Exposure-Win 96-LDGV}} = 0.739\ \mu g/m^3 \times 0.521 = 0.386\ \mu g/m^3$$

Consistent with the fleet-average calculations, annual-average exposure estimates for each vehicle class were prepared by taking the arithmetic mean of the quarterly results for each class.

<u>Results</u> - A detailed summary of the exposure estimates calculated as described above is contained in Volume II for each urban area, calendar year, demographic group, scenario, season, and vehicle class. The annual average exposure estimates for the total population are summarized in Tables 7-5 to 7-10 for benzene, acetaldehyde, formaldehyde, 1,3-butadiene, MTBE, and Diesel PM, respectively. Recall that the four control programs were defined as follows:

0. Baseline fuels and emission rates, assuming the implementation of a National Low-Emission Vehicle (NLEV) program;

1. Baseline emission factors with an assumed national gasoline regulation limiting sulfur levels to 40 ppm;

2. Scenario 1 with more stringent tailpipe hydrocarbon emission standards for light-duty cars and trucks (i.e., reflecting possible Tier 2 standards); and

3. Scenario 2 with an assumed increase in light-duty Diesel truck implementation equivalent to 50% of total light-duty truck sales beginning in model year 2004.

Table 7-5
Annual-Average Exposure Results for Benzene
Total Population - All On-Road Vehicles
(Units: ug/m3)

Area	Scenario	1990 CO Ratio	Calendar Year 1990	1996	2007	2020
Chicago	Base	8.4	0.997	0.567	0.308	0.235
	Sc#1	8.4	---	---	0.292	0.218
	Sc#2	8.4	---	---	0.279	0.164
	Sc#3	8.4	---	---	0.249	0.131
Denver	Base	8.1	0.922	0.871	0.526	0.430
	Sc#1	8.1	---	---	0.470	0.368
	Sc#2	8.1	---	---	0.452	0.285
	Sc#3	8.1	---	---	0.403	0.227
Houston	Base	6.9	0.787	0.530	0.328	0.244
	Sc#1	6.9	---	---	0.314	0.229
	Sc#2	6.9	---	---	0.303	0.178
	Sc#3	6.9	---	---	0.272	0.145
Minneapolis	Base	11.3	1.923	1.414	1.055	0.978
	Sc#1	11.3	---	---	1.035	0.955
	Sc#2	11.3	---	---	0.995	0.795
	Sc#3	11.3	---	---	0.859	0.587
New York	Base	18.0	2.106	0.903	0.527	0.354
	Sc#1	18.0	---	---	0.503	0.331
	Sc#2	18.0	---	---	0.482	0.246
	Sc#3	18.0	---	---	0.430	0.198
Philadelphia	Base	7.8	1.071	0.642	0.290	0.210
	Sc#1	7.8	---	---	0.273	0.193
	Sc#2	7.8	---	---	0.261	0.145
	Sc#3	7.8	---	---	0.232	0.116
Phoenix	Base	14.4	1.923	1.419	0.456	0.378
	Sc#1	14.4	---	---	0.456	0.378
	Sc#2	14.4	---	---	0.437	0.288
	Sc#3	14.4	---	---	0.397	0.236
Spokane	Base	13.6	1.492	1.194	0.682	0.515
	Sc#1	13.6	---	---	0.600	0.431
	Sc#2	13.6	---	---	0.577	0.330
	Sc#3	13.6	---	---	0.511	0.262
St. Louis	Base	6.0	0.690	0.634	0.302	0.234
	Sc#1	6.0	---	---	0.289	0.218
	Sc#2	6.0	---	---	0.276	0.163
	Sc#3	6.0	---	---	0.246	0.130

Table 7-6
Annual-Average Exposure Results for Acetaldehyde[a]
Total Population - All On-Road Vehicles
(Units: ug/m3)

Area	Scenario	1990 CO Ratio	Calendar Year 1990	1996	2007	2020
Chicago	Base	8.4	0.149	0.189	0.094	0.069
	Sc#1	8.4	---	---	0.091	0.066
	Sc#2	8.4	---	---	0.088	0.054
	Sc#3	8.4	---	---	0.084	0.050
Denver	Base	8.1	0.234	0.288	0.147	0.123
	Sc#1	8.1	---	---	0.144	0.117
	Sc#2	8.1	---	---	0.140	0.103
	Sc#3	8.1	---	---	0.137	0.099
Houston	Base	6.9	0.123	0.112	0.060	0.048
	Sc#1	6.9	---	---	0.059	0.047
	Sc#2	6.9	---	---	0.057	0.041
	Sc#3	6.9	---	---	0.059	0.043
Minneapolis	Base	11.3	0.262	0.366	0.218	0.182
	Sc#1	11.3	---	---	0.215	0.178
	Sc#2	11.3	---	---	0.208	0.151
	Sc#3	11.3	---	---	0.189	0.128
New York	Base	18.0	0.312	0.194	0.101	0.071
	Sc#1	18.0	---	---	0.099	0.069
	Sc#2	18.0	---	---	0.097	0.060
	Sc#3	18.0	---	---	0.098	0.063
Philadelphia	Base	7.8	0.169	0.118	0.049	0.037
	Sc#1	7.8	---	---	0.048	0.036
	Sc#2	7.8	---	---	0.047	0.031
	Sc#3	7.8	---	---	0.048	0.032
Phoenix	Base	14.4	0.245	0.312	0.101	0.086
	Sc#1	14.4	---	---	0.101	0.086
	Sc#2	14.4	---	---	0.098	0.076
	Sc#3	14.4	---	---	0.103	0.080
Spokane	Base	13.6	0.277	0.322	0.154	0.115
	Sc#1	13.6	---	---	0.145	0.105
	Sc#2	13.6	---	---	0.141	0.087
	Sc#3	13.6	---	---	0.135	0.082
St. Louis	Base	6.0	0.108	0.103	0.075	0.056
	Sc#1	6.0	---	---	0.074	0.054
	Sc#2	6.0	---	---	0.071	0.045
	Sc#3	6.0	---	---	0.069	0.042

[a] Results not corrected for atmospheric transformation.

Table 7-7
Annual-Average Exposure Results for Formaldehyde[a]
Total Population - All On-Road Vehicles
(Units: ug/m3)

Area	Scenario	1990 CO Ratio	Calendar Year 1990	1996	2007	2020
Chicago	Base	8.4	0.459	0.312	0.167	0.126
	Sc#1	8.4	---	---	0.166	0.125
	Sc#2	8.4	---	---	0.162	0.107
	Sc#3	8.4	---	---	0.165	0.109
Denver	Base	8.1	0.847	0.633	0.313	0.266
	Sc#1	8.1	---	---	0.313	0.265
	Sc#2	8.1	---	---	0.308	0.240
	Sc#3	8.1	---	---	0.314	0.242
Houston	Base	6.9	0.387	0.369	0.200	0.149
	Sc#1	6.9	---	---	0.201	0.149
	Sc#2	6.9	---	---	0.197	0.129
	Sc#3	6.9	---	---	0.199	0.134
Minneapolis	Base	11.3	0.828	0.652	0.348	0.290
	Sc#1	11.3	---	---	0.355	0.300
	Sc#2	11.3	---	---	0.345	0.259
	Sc#3	11.3	---	---	0.332	0.246
New York	Base	18.0	0.991	0.668	0.348	0.223
	Sc#1	18.0	---	---	0.352	0.225
	Sc#2	18.0	---	---	0.343	0.192
	Sc#3	18.0	---	---	0.340	0.197
Philadelphia	Base	7.8	0.534	0.407	0.169	0.117
	Sc#1	7.8	---	---	0.170	0.117
	Sc#2	7.8	---	---	0.166	0.100
	Sc#3	7.8	---	---	0.165	0.102
Phoenix	Base	14.4	0.915	0.638	0.352	0.281
	Sc#1	14.4	---	---	0.352	0.281
	Sc#2	14.4	---	---	0.344	0.244
	Sc#3	14.4	---	---	0.350	0.253
Spokane	Base	13.6	0.874	0.669	0.290	0.220
	Sc#1	13.6	---	---	0.296	0.220
	Sc#2	13.6	---	---	0.288	0.188
	Sc#3	13.6	---	---	0.291	0.191
St. Louis	Base	6.0	0.338	0.291	0.145	0.109
	Sc#1	6.0	---	---	0.146	0.110
	Sc#2	6.0	---	---	0.142	0.094
	Sc#3	6.0	---	---	0.145	0.096

[a] Results not corrected for atmospheric transformation.

Table 7-8
Annual-Average Exposure Results for 1,3-Butadiene
Total Population - All On-Road Vehicles
(Units: ug/m3)

Area	Scenario	1990 CO Ratio	Calendar Year 1990	1996	2007	2020
Chicago	Base	8.4	0.100	0.057	0.028	0.025
	Sc#1	8.4	---	---	0.026	0.022
	Sc#2	8.4	---	---	0.025	0.018
	Sc#3	8.4	---	---	0.025	0.016
Denver	Base	8.1	0.139	0.104	0.049	0.045
	Sc#1	8.1	---	---	0.043	0.039
	Sc#2	8.1	---	---	0.042	0.033
	Sc#3	8.1	---	---	0.041	0.030
Houston	Base	6.9	0.081	0.060	0.031	0.027
	Sc#1	6.9	---	---	0.027	0.023
	Sc#2	6.9	---	---	0.027	0.019
	Sc#3	6.9	---	---	0.027	0.018
Minneapolis	Base	11.3	0.190	0.122	0.082	0.089
	Sc#1	11.3	---	---	0.074	0.079
	Sc#2	11.3	---	---	0.072	0.069
	Sc#3	11.3	---	---	0.066	0.055
New York	Base	18.0	0.229	0.123	0.063	0.048
	Sc#1	18.0	---	---	0.053	0.039
	Sc#2	18.0	---	---	0.052	0.032
	Sc#3	18.0	---	---	0.050	0.029
Philadelphia	Base	7.8	0.130	0.073	0.028	0.023
	Sc#1	7.8	---	---	0.025	0.020
	Sc#2	7.8	---	---	0.024	0.016
	Sc#3	7.8	---	---	0.024	0.015
Phoenix	Base	14.4	0.150	0.112	0.045	0.044
	Sc#1	14.4	---	---	0.045	0.044
	Sc#2	14.4	---	---	0.044	0.036
	Sc#3	14.4	---	---	0.045	0.034
Spokane	Base	13.6	0.186	0.126	0.055	0.046
	Sc#1	13.6	---	---	0.048	0.039
	Sc#2	13.6	---	---	0.047	0.032
	Sc#3	13.6	---	---	0.046	0.028
St. Louis	Base	6.0	0.076	0.071	0.030	0.028
	Sc#1	6.0	---	---	0.027	0.024
	Sc#2	6.0	---	---	0.026	0.019
	Sc#3	6.0	---	---	0.025	0.017

Table 7-9
Annual-Average Exposure Results for MTBE
Total Population - All On-Road Vehicles
(Units: ug/m3)

Area	Scenario	1990 CO Ratio	Calendar Year 1990	1996	2007	2020
Chicago	Base	8.4	0.000	0.000	0.000	0.000
	Sc#1	8.4	---	---	0.000	0.000
	Sc#2	8.4	---	---	0.000	0.000
	Sc#3	8.4	---	---	0.000	0.000
Denver	Base	8.1	0.902	0.000	0.000	0.000
	Sc#1	8.1	---	---	0.000	0.000
	Sc#2	8.1	---	---	0.000	0.000
	Sc#3	8.1	---	---	0.000	0.000
Houston	Base	6.9	0.023	0.883	0.958	0.658
	Sc#1	6.9	---	---	0.971	0.665
	Sc#2	6.9	---	---	0.966	0.642
	Sc#3	6.9	---	---	0.846	0.503
Minneapolis	Base	11.3	0.000	0.000	0.000	0.000
	Sc#1	11.3	---	---	0.000	0.000
	Sc#2	11.3	---	---	0.000	0.000
	Sc#3	11.3	---	---	0.000	0.000
New York	Base	18.0	0.181	1.526	1.052	0.644
	Sc#1	18.0	---	---	1.060	0.647
	Sc#2	18.0	---	---	1.051	0.608
	Sc#3	18.0	---	---	0.907	0.467
Philadelphia	Base	7.8	0.000	0.684	0.423	0.287
	Sc#1	7.8	---	---	0.421	0.284
	Sc#2	7.8	---	---	0.417	0.264
	Sc#3	7.8	---	---	0.362	0.207
Phoenix	Base	14.4	2.109	0.049	1.267	0.994
	Sc#1	14.4	---	---	1.267	0.994
	Sc#2	14.4	---	---	1.260	0.950
	Sc#3	14.4	---	---	1.095	0.731
Spokane	Base	13.6	0.000	0.000	0.000	0.000
	Sc#1	13.6	---	---	0.086	0.049
	Sc#2	13.6	---	---	0.086	0.049
	Sc#3	13.6	---	---	0.074	0.038
St. Louis	Base	6.0	0.000	0.000	0.000	0.000
	Sc#1	6.0	---	---	0.079	0.057
	Sc#2	6.0	---	---	0.079	0.057
	Sc#3	6.0	---	---	0.070	0.045

Table 7-10
Annual-Average Exposure Results for Diesel PM
Total Population - All On-Road Vehicles
(Units: ug/m3)

Area	Scenario	1990 CO Ratio	Calendar Year 1990	1996	2007	2020
Chicago	Base	8.4	0.776	0.566	0.295	0.273
	Sc#1	8.4	---	---	0.295	0.273
	Sc#2	8.4	---	---	0.295	0.273
	Sc#3	8.4	---	---	0.488	0.647
Denver	Base	8.1	0.756	0.700	0.354	0.353
	Sc#1	8.1	---	---	0.354	0.353
	Sc#2	8.1	---	---	0.354	0.353
	Sc#3	8.1	---	---	0.584	0.837
Houston	Base	6.9	0.628	0.756	0.342	0.334
	Sc#1	6.9	---	---	0.342	0.334
	Sc#2	6.9	---	---	0.342	0.334
	Sc#3	6.9	---	---	0.566	0.791
Minneapolis	Base	11.3	1.040	0.866	0.417	0.395
	Sc#1	11.3	---	---	0.417	0.395
	Sc#2	11.3	---	---	0.417	0.395
	Sc#3	11.3	---	---	0.690	0.936
New York	Base	18.0	1.660	1.059	0.533	0.473
	Sc#1	18.0	---	---	0.533	0.473
	Sc#2	18.0	---	---	0.533	0.473
	Sc#3	18.0	---	---	0.882	1.121
Philadelphia	Base	7.8	0.715	0.602	0.257	0.236
	Sc#1	7.8	---	---	0.257	0.236
	Sc#2	7.8	---	---	0.257	0.236
	Sc#3	7.8	---	---	0.425	0.558
Phoenix	Base	14.4	1.379	1.205	0.614	0.631
	Sc#1	14.4	---	---	0.614	0.631
	Sc#2	14.4	---	---	0.614	0.631
	Sc#3	14.4	---	---	1.015	1.495
Spokane	Base	13.6	1.296	1.015	0.486	0.464
	Sc#1	13.6	---	---	0.486	0.464
	Sc#2	13.6	---	---	0.486	0.464
	Sc#3	13.6	---	---	0.805	1.101
St. Louis	Base	6.0	0.574	0.530	0.254	0.234
	Sc#1	6.0	---	---	0.254	0.234
	Sc#2	6.0	---	---	0.254	0.234
	Sc#3	6.0	---	---	0.420	0.555

It is interesting to note that the motor vehicle air toxics exposures are estimated to decrease substantially between 1990 and 2020, even without additional controls on vehicles and fuels. This is a result of fleet-turnover and the full implementation of federal regulations that are currently in place. As one might expect, the benefits of Scenario 1, a national gasoline rule limiting sulfur to 40 ppm, are greatest in areas that do not have a pre-existing reformulated gasoline program such as Minneapolis. Areas with an RFG program show more moderate decreases in motor vehicle toxics exposure, depending on pollutant, as a result of a national gasoline sulfur limit. The more stringent light-duty vehicle emission standards modeled in Scenario 2 in general show greater decreases in toxics exposure than the other control scenarios modeled in this effort, particularly for the 2020 calendar year run. Finally, the increased light-duty Diesel penetration scenario modeled in Scenario 3 results in substantial increases in Diesel particulate exposure levels, although benzene and 1,3-butadiene exposure is decreased. It should be kept in mind that the exposure estimates for acetaldehyde and formaldehyde do not include any adjustments to account for atmospheric transformation.

As discussed above, exposure estimates were also prepared for three different demographic groups: total population, outdoor workers, and children 0-17 years of age. (The estimates given in Tables 7-5 to 7-10 are for the total population.) As with the CO exposure estimates shown in Table 7-1, the exposure to air toxics for outdoor workers is generally about 20% higher than for the total population, while exposure for children is typically slightly below the total population. This is observed in Table 7-11, which shows the annual-average benzene exposure for the three demographic groups analyzed in this study for Chicago under the control scenarios described above. As seen in the table, benzene exposure is highest for outdoor workers (which is the highest exposed demographic group), while children and the total population show similar results.

Also Table 7-11

Table 1-3
Annual-Average Exposure Results for Benzene in Chicago by Demographic Group for All On-Road Motor Vehicles (Units: ug/m3)

Demographic Group	Scenario	1990 CO Ratio	Calendar Year 1990	1996	2007	2020
Total Population	Base	8.4	0.997	0.567	0.308	0.235
	Sc#1	8.4	---	---	0.292	0.218
	Sc#2	8.4	---	---	0.279	0.164
	Sc#3	8.4	---	---	0.249	0.131
Outdoor Workers	Base	10.1	1.200	0.683	0.371	0.283
	Sc#1	10.1	---	---	0.351	0.262
	Sc#2	10.1	---	---	0.336	0.197
	Sc#3	10.1	---	---	0.300	0.158
Children 0 - 17 Years	Base	8.2	0.980	0.557	0.303	0.231
	Sc#1	8.2	---	---	0.287	0.214
	Sc#2	8.2	---	---	0.274	0.161
	Sc#3	8.2	---	---	0.245	0.129

8. RISK ASSESSMENT

Using the on-road motor vehicle toxic exposure estimates generated in Section 7, estimates of individual cancer risk can be calculated from the following formula:

$$CAN_{Ind} = TOX_{Exposure\text{-}Adj\ (\mu g/m3)} \times (UR / YPL)$$

where $TOX_{Exposure\text{-}Adj\ (\mu g/m3)}$ is the adjusted toxic exposure estimates generated in Section 7; UR is the unit risk in cancer cases or deaths per person exposed in a lifetime to 1 $\mu g/m^3$ of the toxic compound of interest; and YPL is years per lifetime (typically assumed to be 70 years).

To calculate the total cancer cases for the population, the individual cancer risk defined above is simply multiplied by the population subject to the toxic compound exposure, i.e.,

$$CAN_{Pop} = CAN_{Ind} \times \text{Population}$$

Because EPA has not yet finalized revised unit risk estimates, Sierra was directed to only set up a methodology to calculate individual risk and cancer incidences. This was accomplished within the FORTRAN routine developed to generate the exposure estimates. That model was structured to allow a user to input two estimates of unit risk for each pollutant (a lower bound and an upper bound), as well as alternative years per lifetime estimates. Individual risk is reported in terms of cancer cases per million people, and total cancer cases are calculated based on the population in each area. Estimates are prepared for each of the nine modeled areas under the entire suite of forecast years and control scenarios for which exposure is estimated.

A copy of the individual cancer risk output from the model is given in Table 8-1 for benzene for the nine urban areas modeled in this effort (performed for the total population and all vehicle classes). Note that the range of unit risk values used in this analysis was chosen simply for calculational purposes. It is not necessarily reflective of the values EPA may ultimately use in its analyses.

Table 8-1

Sample Output from the Exposure Model
Benzene Cancer Incidences per Million People

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Cancer Incidences Per Million People for Benzene

Demographic Group: All
Vehicle Class: All Veh
Low-Range Unit Risk (per million): 8.300
High-Range Unit Risk (per million): 15.000
Assumed Years Per Lifetime: 70.0

		CY1990		CY1996		CY2007		CY2020	
Area	Scen	Low	High	Low	High	Low	High	Low	High
CHICAGO	Base	0.1182	0.2136	0.0672	0.1215	0.0366	0.0661	0.0279	0.0504
CHICAGO	Sc#1	---	---	---	---	0.0346	0.0625	0.0258	0.0467
CHICAGO	Sc#2	---	---	---	---	0.0330	0.0597	0.0194	0.0351
CHICAGO	Sc#3	---	---	---	---	0.0295	0.0534	0.0155	0.0280
DENVER	Base	0.1093	0.1975	0.1033	0.1866	0.0624	0.1127	0.0510	0.0922
DENVER	Sc#1	---	---	---	---	0.0558	0.1008	0.0436	0.0789
DENVER	Sc#2	---	---	---	---	0.0536	0.0968	0.0338	0.0610
DENVER	Sc#3	---	---	---	---	0.0478	0.0864	0.0269	0.0486
HOUSTON	Base	0.0933	0.1686	0.0628	0.1135	0.0389	0.0702	0.0289	0.0523
HOUSTON	Sc#1	---	---	---	---	0.0372	0.0673	0.0271	0.0491
HOUSTON	Sc#2	---	---	---	---	0.0359	0.0648	0.0211	0.0382
HOUSTON	Sc#3	---	---	---	---	0.0322	0.0582	0.0172	0.0311
MINNEAPOLIS	Base	0.2280	0.4120	0.1676	0.3029	0.1251	0.2261	0.1159	0.2095
MINNEAPOLIS	Sc#1	---	---	---	---	0.1227	0.2218	0.1133	0.2047
MINNEAPOLIS	Sc#2	---	---	---	---	0.1180	0.2133	0.0943	0.1704
MINNEAPOLIS	Sc#3	---	---	---	---	0.1018	0.1840	0.0696	0.1257
NEW YORK	Base	0.2497	0.4512	0.1071	0.1936	0.0625	0.1129	0.0419	0.0758
NEW YORK	Sc#1	---	---	---	---	0.0597	0.1078	0.0392	0.0709
NEW YORK	Sc#2	---	---	---	---	0.0571	0.1033	0.0292	0.0527
NEW YORK	Sc#3	---	---	---	---	0.0509	0.0920	0.0235	0.0424
PHILADELPHIA	Base	0.1269	0.2294	0.0761	0.1375	0.0344	0.0621	0.0248	0.0449
PHILADELPHIA	Sc#1	---	---	---	---	0.0323	0.0584	0.0229	0.0414
PHILADELPHIA	Sc#2	---	---	---	---	0.0309	0.0559	0.0171	0.0310
PHILADELPHIA	Sc#3	---	---	---	---	0.0275	0.0497	0.0137	0.0248
PHOENIX	Base	0.2281	0.4122	0.1682	0.3040	0.0540	0.0976	0.0448	0.0810
PHOENIX	Sc#1	---	---	---	---	0.0540	0.0976	0.0448	0.0810
PHOENIX	Sc#2	---	---	---	---	0.0518	0.0936	0.0341	0.0617
PHOENIX	Sc#3	---	---	---	---	0.0470	0.0850	0.0279	0.0505
SPOKANE	Base	0.1769	0.3197	0.1416	0.2560	0.0809	0.1462	0.0610	0.1103
SPOKANE	Sc#1	---	---	---	---	0.0711	0.1285	0.0510	0.0923
SPOKANE	Sc#2	---	---	---	---	0.0684	0.1236	0.0392	0.0708
SPOKANE	Sc#3	---	---	---	---	0.0605	0.1094	0.0311	0.0562
ST LOUIS	Base	0.0819	0.1479	0.0751	0.1358	0.0358	0.0648	0.0277	0.0501
ST LOUIS	Sc#1	---	---	---	---	0.0343	0.0620	0.0258	0.0466
ST LOUIS	Sc#2	---	---	---	---	0.0327	0.0592	0.0193	0.0349
ST LOUIS	Sc#3	---	---	---	---	0.0292	0.0528	0.0154	0.0278

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Appendix A

Revised TOG and CO Inputs Used in the MOBILE Emissions Modeling

The following inputs and data are included in this appendix:

1. TOG/NMHC Ratios

2. Alternative TOG base emission rate equations for the following scenarios:

   a. Non-OTR NLEV, I/M, baseline emission factors
   b. Non-OTR NLEV, I/M, Tier 2 control
   c. Non-OTR NLEV, Non-I/M, baseline emission factors
   d. Non-OTR NLEV, Non-I/M, Tier 2 control
   e. OTR NLEV, I/M, baseline emission factors
   f. OTR NLEV, I/M, Tier 2 control
   g. Denver - Non-OTR NLEV, I/M, baseline emission factors
   h. Denver - Non-OTR NLEV, I/M, Tier 2 control

3. Off-cycle TOG correction factors

   a. I/M, 1990
   b. I/M, 1996 and later
   c. Non-I/M, 1990
   d. Non-I/M, 1996
   e. Non-I/M, 2007 and later

4. Alternative CO base emission rate equations for the following:

   a. Low-altitude
   b. High-altitude (Denver)

5. Off-Cycle CO correction factors (I/M and non-I/M combined)

6. Air conditioning data for CO estimates (fraction equipped, malfunction rates)

7. Oxygenated fuels CO effects

TOG/NMHC Correction Factors by Model Year and Vehicle Class

MY	LDGV	LDGT1	LDGT2	HDGV	LDDV	LDDT	HDDV	MC
1965	1.099	1.099	1.099	1.252	1.1094	1.1094	1.1294	1.099
1966	1.099	1.099	1.099	1.252	1.1094	1.1094	1.1294	1.099
1967	1.099	1.099	1.099	1.252	1.1094	1.1094	1.1294	1.099
1968	1.099	1.099	1.099	1.252	1.1094	1.1094	1.1294	1.099
1969	1.099	1.099	1.099	1.252	1.1094	1.1094	1.1294	1.099
1970	1.099	1.099	1.099	1.252	1.1094	1.1094	1.1294	1.099
1971	1.099	1.099	1.099	1.252	1.1094	1.1094	1.1294	1.099
1972	1.099	1.099	1.099	1.252	1.1094	1.1094	1.1294	1.099
1973	1.099	1.099	1.099	1.252	1.1094	1.1094	1.1294	1.099
1974	1.099	1.099	1.099	1.252	1.1094	1.1094	1.1294	1.099
1975	1.158	1.150	1.099	1.252	1.1094	1.1094	1.1294	1.099
1976	1.161	1.158	1.099	1.252	1.1094	1.1094	1.1294	1.099
1977	1.161	1.154	1.099	1.252	1.1094	1.1094	1.1294	1.099
1978	1.165	1.154	1.099	1.252	1.1094	1.1094	1.1294	1.099
1979	1.165	1.158	1.173	1.252	1.1094	1.1094	1.1294	1.099
1980	1.184	1.158	1.173	1.252	1.1094	1.1094	1.1294	1.099
1981	1.290	1.174	1.173	1.252	1.1094	1.1094	1.1294	1.099
1982	1.291	1.174	1.173	1.271	1.1094	1.1094	1.1294	1.099
1983	1.311	1.190	1.194	1.271	1.1094	1.1094	1.1294	1.099
1984	1.307	1.221	1.236	1.271	1.1094	1.1094	1.1294	1.099
1985	1.280	1.213	1.257	1.271	1.1094	1.1094	1.1294	1.099
1986	1.264	1.197	1.278	1.271	1.1094	1.1094	1.1294	1.099
1987	1.246	1.222	1.287	1.367	1.1094	1.1094	1.1294	1.099
1988	1.209	1.221	1.276	1.406	1.1094	1.1094	1.1294	1.099
1989	1.199	1.234	1.276	1.406	1.1094	1.1094	1.1294	1.099
1990	1.197	1.212	1.276	1.610	1.1094	1.1094	1.1294	1.099
1991	1.184	1.149	1.149	1.610	1.1094	1.1094	1.1294	1.099
1992	1.177	1.196	1.196	1.610	1.1094	1.1094	1.1294	1.099
1993	1.169	1.194	1.194	1.610	1.1094	1.1094	1.1294	1.099
1994	1.169	1.192	1.192	1.610	1.1094	1.1094	1.1294	1.099
1995	1.169	1.192	1.192	1.610	1.1094	1.1094	1.1294	1.099
1996	1.169	1.194	1.194	1.618	1.1094	1.1094	1.1294	1.099
1997	1.169	1.194	1.194	1.618	1.1094	1.1094	1.1294	1.099
1998	1.169	1.194	1.194	1.618	1.1094	1.1094	1.1294	1.099
1999	1.169	1.194	1.194	1.618	1.1094	1.1094	1.1294	1.099
2000	1.169	1.194	1.194	1.629	1.1094	1.1094	1.1294	1.099
2001	1.169	1.182	1.182	1.629	1.1094	1.1094	1.1294	1.099
2002	1.169	1.182	1.182	1.629	1.1094	1.1094	1.1294	1.099
2003	1.169	1.182	1.182	1.629	1.1094	1.1094	1.1294	1.099
2004	1.169	1.182	1.182	1.637	1.1094	1.1094	1.1294	1.099

TOG BERs - I/M Non-OTR Baseline Case

0099					ZM	DR1	DR2	Flex Pt	File: NTR_IM_B.BER	
1	1	1	65	67	7.488	0.186			LDGV	
1	1	1	68	69	4.576	0.258				
1	1	1	70	71	3.099	0.382				
1	1	1	72	74	3.491	0.165				
1	1	1	75	75	1.068	0.282				
1	1	1	76	77	1.071	0.283				
1	1	1	78	79	1.074	0.284				
1	1	1	80	80	0.371	0.211				
1	1	1	81	82	0.398	0.149	0.209	1.53		
1	1	1	83	83	0.258	0.051	0.140	2.22		
1	1	1	84	84	0.257	0.051	0.140	2.22		
1	1	1	85	85	0.251	0.050	0.137	2.22		
1	1	1	86	86	0.303	0.058				
1	1	1	87	87	0.299	0.057				
1	1	1	88	88	0.290	0.056				
1	1	1	89	89	0.288	0.055				
1	1	1	90	90	0.200	0.019	0.040	2.13		
1	1	1	91	91	0.198	0.018	0.040	2.13		
1	1	1	92	92	0.197	0.018	0.040	2.13		
1	1	1	93	94	0.195	0.018	0.040	2.13		
1	1	1	95	00	0.169	0.011	0.022	8.90		
1	1	1	01	03	0.094	0.009	0.015	7.87	Includes LEV Sulfur Corr	1.36
1	1	1	04	50	0.094	0.009	0.015	7.87	Includes LEV Sulfur Corr	1.36
1	2	1	65	67	7.488	0.186			LDGT1	
1	2	1	68	69	4.576	0.258				
1	2	1	70	71	3.099	0.382				
1	2	1	72	74	3.470	0.176				
1	2	1	75	75	1.802	0.270				
1	2	1	76	76	1.813	0.272				
1	2	1	77	78	1.807	0.271				
1	2	1	79	80	0.876	0.282				
1	2	1	81	82	1.140	0.044	0.143	1.73		
1	2	1	83	83	1.156	0.045	0.145	1.73		
1	2	1	84	84	0.486	0.022	0.108	4.41		
1	2	1	85	85	0.483	0.022	0.107	4.41		
1	2	1	86	86	0.477	0.022	0.106	4.41		
1	2	1	87	87	0.487	0.022	0.108	4.41		
1	2	1	88	88	0.486	0.022	0.108	4.41		
1	2	1	89	89	0.491	0.022	0.109	4.41		
1	2	1	90	90	0.323	0.018	0.047	2.13		
1	2	1	91	91	0.306	0.017	0.044	2.13		
1	2	1	92	93	0.318	0.017	0.046	2.13		
1	2	1	94	94	0.317	0.017	0.046	2.13		
1	2	1	95	00	0.214	0.012	0.025	9.06		
1	2	1	01	03	0.110	0.008	0.016	8.29	Includes LEV Sulfur Corr	1.23
1	2	1	04	50	0.110	0.008	0.016	8.29	Includes LEV Sulfur Corr	1.23
1	3	1	65	69	9.885	0.186			LDGT2	
1	3	1	70	73	6.486	0.258				
1	3	1	74	78	6.486	0.176				
1	3	1	79	80	0.887	0.286				
1	3	1	81	82	1.139	0.044	0.143	1.73		
1	3	1	83	83	1.159	0.045	0.146	1.73		
1	3	1	84	84	0.492	0.022	0.109	4.41		
1	3	1	85	85	0.500	0.023	0.111	4.41		
1	3	1	86	86	0.509	0.023	0.113	4.41		
1	3	1	87	87	0.513	0.023	0.114	4.41		
1	3	1	88	88	0.508	0.023	0.113	4.41		
1	3	1	89	89	0.508	0.023	0.113	4.41		

1	3	1	90	90	0.340	0.019	0.049	2.13		
1	3	1	91	91	0.306	0.017	0.044	2.13		
1	3	1	92	93	0.318	0.017	0.046	2.13		
1	3	1	94	95	0.317	0.017	0.046	2.13		
1	3	1	96	96	0.318	0.017	0.046	2.13		
1	3	1	97	00	0.260	0.012	0.030	9.25		
1	3	1	01	03	0.258	0.012	0.030	9.25		
1	3	1	04	50	0.258	0.012	0.030	9.25		
1	4	1	94	94	0.586	0.037			HDGV	
1	4	1	95	95	0.586	0.037				
1	4	1	96	96	0.589	0.037				
1	4	1	97	97	0.589	0.037				
1	4	1	98	98	0.589	0.037				
1	4	1	99	99	0.589	0.037				
1	4	1	00	00	0.593	0.037				
1	4	1	01	01	0.593	0.037				
1	4	1	02	02	0.593	0.037				
1	4	1	03	03	0.593	0.037				
1	4	1	04	50	0.453	0.029				
1	5	1	95	95	0.161	0.011	0.021	8.90	LDDV	
1	5	1	96	96	0.161	0.011	0.021	8.90		
1	5	1	97	97	0.161	0.011	0.021	8.90		
1	5	1	98	98	0.161	0.011	0.021	8.90		
1	5	1	99	99	0.161	0.011	0.021	8.90		
1	5	1	00	00	0.161	0.011	0.021	8.90		
1	5	1	01	01	0.066	0.006	0.011	7.87		
1	5	1	02	02	0.066	0.006	0.011	7.87		
1	5	1	03	03	0.066	0.006	0.011	7.87		
1	5	1	04	50	0.066	0.006	0.011	7.87		
1	6	1	95	95	0.271	0.015	0.038	3.87	LDDT	Assumes 25% LDT1 and 75% LDT2
1	6	1	96	96	0.271	0.015	0.038	3.87		
1	6	1	97	97	0.231	0.011	0.027	9.21		
1	6	1	98	98	0.231	0.011	0.027	9.21		
1	6	1	99	99	0.231	0.011	0.027	9.21		
1	6	1	00	00	0.231	0.011	0.027	9.21		
1	6	1	01	01	0.202	0.010	0.024	9.01		
1	6	1	02	02	0.202	0.010	0.024	9.01		
1	6	1	03	03	0.202	0.010	0.024	9.01		
1	6	1	04	50	0.202	0.010	0.024	9.01		
1	7	1	94	03	0.320	0.000			HDDV	
1	7	1	04	50	0.290	0.000				

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TOG BERs - I/M Non-OTR Control Case
0099            ZM    DR1    DR2 Flex Pt  File: NTR_IM_C.BER
1 1 1 65 67  7.488  0.186                       LDGV
1 1 1 68 69  4.576  0.258
1 1 1 70 71  3.099  0.382
1 1 1 72 74  3.491  0.165
1 1 1 75 75  1.068  0.282
1 1 1 76 77  1.071  0.283
1 1 1 78 79  1.074  0.284
1 1 1 80 80  0.371  0.211
1 1 1 81 82  0.398  0.149  0.209   1.53
1 1 1 83 83  0.258  0.051  0.140   2.22
1 1 1 84 84  0.257  0.051  0.140   2.22
1 1 1 85 85  0.251  0.050  0.137   2.22
1 1 1 86 86  0.303  0.058
1 1 1 87 87  0.299  0.057
1 1 1 88 88  0.290  0.056
1 1 1 89 89  0.288  0.055
1 1 1 90 90  0.200  0.019  0.040   2.13
1 1 1 91 91  0.198  0.018  0.040   2.13
1 1 1 92 92  0.197  0.018  0.040   2.13
1 1 1 93 94  0.195  0.018  0.040   2.13
1 1 1 95 00  0.169  0.011  0.022   8.90
1 1 1 01 03  0.094  0.009  0.015   7.87         Includes LEV Sulfur Corr    1.36
1 1 1 04 50  0.057  0.008  0.014   8.10         Includes LEV Sulfur Corr    1.36
1 2 1 65 67  7.488  0.186                       LDGT1
1 2 1 68 69  4.576  0.258
1 2 1 70 71  3.099  0.382
1 2 1 72 74  3.470  0.176
1 2 1 75 75  1.802  0.270
1 2 1 76 76  1.813  0.272
1 2 1 77 78  1.807  0.271
1 2 1 79 80  0.876  0.282
1 2 1 81 82  1.140  0.044  0.143   1.73
1 2 1 83 83  1.156  0.045  0.145   1.73
1 2 1 84 84  0.486  0.022  0.108   4.41
1 2 1 85 85  0.483  0.022  0.107   4.41
1 2 1 86 86  0.477  0.022  0.106   4.41
1 2 1 87 87  0.487  0.022  0.108   4.41
1 2 1 88 88  0.486  0.022  0.108   4.41
1 2 1 89 89  0.491  0.022  0.109   4.41
1 2 1 90 90  0.323  0.018  0.047   2.13
1 2 1 91 91  0.306  0.017  0.044   2.13
1 2 1 92 93  0.318  0.017  0.046   2.13
1 2 1 94 94  0.317  0.017  0.046   2.13
1 2 1 95 00  0.214  0.012  0.025   9.06
1 2 1 01 03  0.110  0.008  0.016   8.29         Includes LEV Sulfur Corr    1.23
1 2 1 04 50  0.058  0.008  0.014   8.10         Includes LEV Sulfur Corr    1.36
1 3 1 65 69  9.885  0.186                       LDGT2
1 3 1 70 73  6.486  0.258
1 3 1 74 78  6.486  0.176
1 3 1 79 80  0.887  0.286
1 3 1 81 82  1.139  0.044  0.143   1.73
1 3 1 83 83  1.159  0.045  0.146   1.73
1 3 1 84 84  0.492  0.022  0.109   4.41
1 3 1 85 85  0.500  0.023  0.111   4.41
1 3 1 86 86  0.509  0.023  0.113   4.41
1 3 1 87 87  0.513  0.023  0.114   4.41
1 3 1 88 88  0.508  0.023  0.113   4.41
1 3 1 89 89  0.508  0.023  0.113   4.41
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1	3	1	90	90	0.340	0.019	0.049	2.13		
1	3	1	91	91	0.306	0.017	0.044	2.13		
1	3	1	92	93	0.318	0.017	0.046	2.13		
1	3	1	94	95	0.317	0.017	0.046	2.13		
1	3	1	96	96	0.318	0.017	0.046	2.13		
1	3	1	97	00	0.260	0.012	0.030	9.25		
1	3	1	01	03	0.258	0.012	0.030	9.25		
1	3	1	04	50	0.058	0.008	0.014	8.10	Includes LEV Sulfur Corr	1.36
1	4	1	94	94	0.586	0.037			HDGV	
1	4	1	95	95	0.586	0.037				
1	4	1	96	96	0.589	0.037				
1	4	1	97	97	0.589	0.037				
1	4	1	98	98	0.589	0.037				
1	4	1	99	99	0.589	0.037				
1	4	1	00	00	0.593	0.037				
1	4	1	01	01	0.593	0.037				
1	4	1	02	02	0.593	0.037				
1	4	1	03	03	0.593	0.037				
1	4	1	04	50	0.453	0.029				
1	5	1	95	95	0.161	0.011	0.021	8.90	LDDV	
1	5	1	96	96	0.161	0.011	0.021	8.90		
1	5	1	97	97	0.161	0.011	0.021	8.90		
1	5	1	98	98	0.161	0.011	0.021	8.90		
1	5	1	99	99	0.161	0.011	0.021	8.90		
1	5	1	00	00	0.161	0.011	0.021	8.90		
1	5	1	01	01	0.066	0.006	0.011	7.87		
1	5	1	02	02	0.066	0.006	0.011	7.87		
1	5	1	03	03	0.066	0.006	0.011	7.87		
1	5	1	04	50	0.040	0.006	0.010	8.10		
1	6	1	95	95	0.271	0.015	0.038	3.87	LDDT	Assumes 25% LDT1 and 75% LDT2
1	6	1	96	96	0.271	0.015	0.038	3.87		
1	6	1	97	97	0.231	0.011	0.027	9.21		
1	6	1	98	98	0.231	0.011	0.027	9.21		
1	6	1	99	99	0.231	0.011	0.027	9.21		
1	6	1	00	00	0.231	0.011	0.027	9.21		
1	6	1	01	01	0.202	0.010	0.024	9.01		
1	6	1	02	02	0.202	0.010	0.024	9.01		
1	6	1	03	03	0.202	0.010	0.024	9.01		
1	6	1	04	50	0.040	0.006	0.010	8.10		
1	7	1	94	03	0.320	0.000			HDDV	
1	7	1	04	50	0.290	0.000				

TOG BERs - Non-I/M Non-OTR Baseline Case

0099					ZM	DR1	DR2	Flex Pt	File: NTR_NO_B.BER	
1	1	1	65	67	7.488	0.186			LDGV	
1	1	1	68	69	4.576	0.258				
1	1	1	70	71	3.099	0.382				
1	1	1	72	74	3.491	0.165				
1	1	1	75	75	1.068	0.282				
1	1	1	76	77	1.071	0.283				
1	1	1	78	79	1.074	0.284				
1	1	1	80	80	0.371	0.211				
1	1	1	81	82	0.398	0.149	0.209	1.53		
1	1	1	83	83	0.258	0.051	0.140	2.22		
1	1	1	84	84	0.257	0.051	0.140	2.22		
1	1	1	85	85	0.251	0.050	0.137	2.22		
1	1	1	86	86	0.303	0.058				
1	1	1	87	87	0.299	0.057				
1	1	1	88	88	0.290	0.056				
1	1	1	89	89	0.288	0.055				
1	1	1	90	90	0.200	0.019	0.040	2.13		
1	1	1	91	91	0.198	0.018	0.040	2.13		
1	1	1	92	92	0.197	0.018	0.040	2.13		
1	1	1	93	94	0.195	0.018	0.040	2.13		
1	1	1	95	00	0.169	0.016	0.038	6.70		
1	1	1	01	03	0.094	0.016	0.048	6.77	Includes LEV Sulfur Corr	1.36
1	1	1	04	50	0.094	0.016	0.048	6.77	Includes LEV Sulfur Corr	1.36
1	2	1	65	67	7.488	0.186			LDGT1	
1	2	1	68	69	4.576	0.258				
1	2	1	70	71	3.099	0.382				
1	2	1	72	74	3.470	0.176				
1	2	1	75	75	1.802	0.270				
1	2	1	76	76	1.813	0.272				
1	2	1	77	78	1.807	0.271				
1	2	1	79	80	0.876	0.282				
1	2	1	81	82	1.140	0.044	0.143	1.73		
1	2	1	83	83	1.156	0.045	0.145	1.73		
1	2	1	84	84	0.486	0.022	0.108	4.41		
1	2	1	85	85	0.483	0.022	0.107	4.41		
1	2	1	86	86	0.477	0.022	0.106	4.41		
1	2	1	87	87	0.487	0.022	0.108	4.41		
1	2	1	88	88	0.486	0.022	0.108	4.41		
1	2	1	89	89	0.491	0.022	0.109	4.41		
1	2	1	90	90	0.323	0.018	0.047	2.13		
1	2	1	91	91	0.306	0.017	0.044	2.13		
1	2	1	92	93	0.318	0.017	0.046	2.13		
1	2	1	94	94	0.317	0.017	0.046	2.13		
1	2	1	95	00	0.213	0.018	0.039	7.27		
1	2	1	01	03	0.110	0.017	0.044	3.09	Includes LEV Sulfur Corr	1.23
1	2	1	04	50	0.110	0.017	0.044	3.09	Includes LEV Sulfur Corr	1.23
1	3	1	65	69	9.885	0.186			LDGT2	
1	3	1	70	73	6.486	0.258				
1	3	1	74	78	6.486	0.176				
1	3	1	79	80	0.887	0.286				
1	3	1	81	82	1.139	0.044	0.143	1.73		
1	3	1	83	83	1.159	0.045	0.146	1.73		
1	3	1	84	84	0.492	0.022	0.109	4.41		
1	3	1	85	85	0.500	0.023	0.111	4.41		
1	3	1	86	86	0.509	0.023	0.113	4.41		
1	3	1	87	87	0.513	0.023	0.114	4.41		
1	3	1	88	88	0.508	0.023	0.113	4.41		
1	3	1	89	89	0.508	0.023	0.113	4.41		

1	3	1	90	90	0.340	0.019	0.049	2.13		
1	3	1	91	91	0.306	0.017	0.044	2.13		
1	3	1	92	93	0.318	0.017	0.046	2.13		
1	3	1	94	95	0.317	0.017	0.046	2.13		
1	3	1	96	96	0.318	0.017	0.046	2.13		
1	3	1	97	00	0.260	0.018	0.039	7.49		
1	3	1	01	03	0.257	0.018	0.039	7.49		
1	3	1	04	50	0.257	0.018	0.039	7.49		
1	4	1	94	94	0.586	0.037			HDGV	
1	4	1	95	95	0.586	0.037				
1	4	1	96	96	0.589	0.037				
1	4	1	97	97	0.589	0.037				
1	4	1	98	98	0.589	0.037				
1	4	1	99	99	0.589	0.037				
1	4	1	00	00	0.593	0.037				
1	4	1	01	01	0.593	0.037				
1	4	1	02	02	0.593	0.037				
1	4	1	03	03	0.593	0.037				
1	4	1	04	50	0.453	0.029				
1	5	1	95	95	0.161	0.015	0.036	6.70	LDDV	
1	5	1	96	96	0.161	0.015	0.036	6.70		
1	5	1	97	97	0.161	0.015	0.036	6.70		
1	5	1	98	98	0.161	0.015	0.036	6.70		
1	5	1	99	99	0.161	0.015	0.036	6.70		
1	5	1	00	00	0.161	0.015	0.036	6.70		
1	5	1	01	01	0.066	0.011	0.034	6.77		
1	5	1	02	02	0.066	0.011	0.034	6.77		
1	5	1	03	03	0.066	0.011	0.034	6.77		
1	5	1	04	50	0.066	0.011	0.034	6.77		
1	6	1	95	95	0.271	0.016	0.041	3.42	LDDT	Assumes 25% LDT1 and 75% LDT2
1	6	1	96	96	0.271	0.016	0.041	3.42		
1	6	1	97	97	0.231	0.017	0.036	7.44		
1	6	1	98	98	0.231	0.017	0.036	7.44		
1	6	1	99	99	0.231	0.017	0.036	7.44		
1	6	1	00	00	0.231	0.017	0.036	7.44		
1	6	1	01	01	0.202	0.016	0.036	6.39		
1	6	1	02	02	0.202	0.016	0.036	6.39		
1	6	1	03	03	0.202	0.016	0.036	6.39		
1	6	1	04	50	0.202	0.016	0.036	6.39		
1	7	1	94	03	0.320	0.000			HDDV	
1	7	1	04	50	0.290	0.000				

TOG BERs - Non-I/M Non-OTR Control Case

0099					ZM	DR1	DR2	Flex Pt	File:	NTR_NO_C.BER	
1	1	1	65	67	7.488	0.186				LDGV	
1	1	1	68	69	4.576	0.258					
1	1	1	70	71	3.099	0.382					
1	1	1	72	74	3.491	0.165					
1	1	1	75	75	1.068	0.282					
1	1	1	76	77	1.071	0.283					
1	1	1	78	79	1.074	0.284					
1	1	1	80	80	0.371	0.211					
1	1	1	81	82	0.398	0.149	0.209	1.53			
1	1	1	83	83	0.258	0.051	0.140	2.22			
1	1	1	84	84	0.257	0.051	0.140	2.22			
1	1	1	85	85	0.251	0.050	0.137	2.22			
1	1	1	86	86	0.303	0.058					
1	1	1	87	87	0.299	0.057					
1	1	1	88	88	0.290	0.056					
1	1	1	89	89	0.288	0.055					
1	1	1	90	90	0.200	0.019	0.040	2.13			
1	1	1	91	91	0.198	0.018	0.040	2.13			
1	1	1	92	92	0.197	0.018	0.040	2.13			
1	1	1	93	94	0.195	0.018	0.040	2.13			
1	1	1	95	00	0.169	0.016	0.038	6.70			
1	1	1	01	03	0.094	0.016	0.048	6.77		Includes LEV Sulfur Corr	1.36
1	1	1	04	50	0.057	0.010	0.046	5.77		Includes LEV Sulfur Corr	1.36
1	2	1	65	67	7.488	0.186				LDGT1	
1	2	1	68	69	4.576	0.258					
1	2	1	70	71	3.099	0.382					
1	2	1	72	74	3.470	0.176					
1	2	1	75	75	1.802	0.270					
1	2	1	76	76	1.813	0.272					
1	2	1	77	78	1.807	0.271					
1	2	1	79	80	0.876	0.282					
1	2	1	81	82	1.140	0.044	0.143	1.73			
1	2	1	83	83	1.156	0.045	0.145	1.73			
1	2	1	84	84	0.486	0.022	0.108	4.41			
1	2	1	85	85	0.483	0.022	0.107	4.41			
1	2	1	86	86	0.477	0.022	0.106	4.41			
1	2	1	87	87	0.487	0.022	0.108	4.41			
1	2	1	88	88	0.486	0.022	0.108	4.41			
1	2	1	89	89	0.491	0.022	0.109	4.41			
1	2	1	90	90	0.323	0.018	0.047	2.13			
1	2	1	91	91	0.306	0.017	0.044	2.13			
1	2	1	92	93	0.318	0.017	0.046	2.13			
1	2	1	94	94	0.317	0.017	0.046	2.13			
1	2	1	95	00	0.213	0.018	0.039	7.27			
1	2	1	01	03	0.110	0.017	0.044	3.09		Includes LEV Sulfur Corr	1.23
1	2	1	04	50	0.058	0.010	0.047	5.77		Includes LEV Sulfur Corr	1.36
1	3	1	65	69	9.885	0.186				LDGT2	
1	3	1	70	73	6.486	0.258					
1	3	1	74	78	6.486	0.176					
1	3	1	79	80	0.887	0.286					
1	3	1	81	82	1.139	0.044	0.143	1.73			
1	3	1	83	83	1.159	0.045	0.146	1.73			
1	3	1	84	84	0.492	0.022	0.109	4.41			
1	3	1	85	85	0.500	0.023	0.111	4.41			
1	3	1	86	86	0.509	0.023	0.113	4.41			
1	3	1	87	87	0.513	0.023	0.114	4.41			
1	3	1	88	88	0.508	0.023	0.113	4.41			
1	3	1	89	89	0.508	0.023	0.113	4.41			

1	3	1	90	90	0.340	0.019	0.049	2.13	
1	3	1	91	91	0.306	0.017	0.044	2.13	
1	3	1	92	93	0.318	0.017	0.046	2.13	
1	3	1	94	95	0.317	0.017	0.046	2.13	
1	3	1	96	96	0.318	0.017	0.046	2.13	
1	3	1	97	00	0.260	0.018	0.039	7.49	
1	3	1	01	03	0.257	0.018	0.039	7.49	
1	3	1	04	50	0.058	0.010	0.047	5.77	Includes LEV Sulfur Corr 1.36
1	4	1	94	94	0.586	0.037			HDGV
1	4	1	95	95	0.586	0.037			
1	4	1	96	96	0.589	0.037			
1	4	1	97	97	0.589	0.037			
1	4	1	98	98	0.589	0.037			
1	4	1	99	99	0.589	0.037			
1	4	1	00	00	0.593	0.037			
1	4	1	01	01	0.593	0.037			
1	4	1	02	02	0.593	0.037			
1	4	1	03	03	0.593	0.037			
1	4	1	04	50	0.453	0.029			
1	5	1	95	95	0.161	0.015	0.036	6.70	LDDV
1	5	1	96	96	0.161	0.015	0.036	6.70	
1	5	1	97	97	0.161	0.015	0.036	6.70	
1	5	1	98	98	0.161	0.015	0.036	6.70	
1	5	1	99	99	0.161	0.015	0.036	6.70	
1	5	1	00	00	0.161	0.015	0.036	6.70	
1	5	1	01	01	0.066	0.011	0.034	6.77	
1	5	1	02	02	0.066	0.011	0.034	6.77	
1	5	1	03	03	0.066	0.011	0.034	6.77	
1	5	1	04	50	0.040	0.007	0.032	5.77	
1	6	1	95	95	0.271	0.016	0.041	3.42	LDDT Assumes 25% LDT1 and 75% LDT2
1	6	1	96	96	0.271	0.016	0.041	3.42	
1	6	1	97	97	0.231	0.017	0.036	7.44	
1	6	1	98	98	0.231	0.017	0.036	7.44	
1	6	1	99	99	0.231	0.017	0.036	7.44	
1	6	1	00	00	0.231	0.017	0.036	7.44	
1	6	1	01	01	0.202	0.016	0.036	6.39	
1	6	1	02	02	0.202	0.016	0.036	6.39	
1	6	1	03	03	0.202	0.016	0.036	6.39	
1	6	1	04	50	0.040	0.007	0.032	5.77	
1	7	1	94	03	0.320	0.000			HDDV
1	7	1	04	50	0.290	0.000			

TOG BERs - I/M OTR Baseline Case

0099	ZM	DR1	DR2	Flex Pt	File: OTR_IM_B.BER	
1 1 1 65 67	7.488	0.186			LDGV	
1 1 1 68 69	4.576	0.258				
1 1 1 70 71	3.099	0.382				
1 1 1 72 74	3.491	0.165				
1 1 1 75 75	1.068	0.282				
1 1 1 76 77	1.071	0.283				
1 1 1 78 79	1.074	0.284				
1 1 1 80 80	0.371	0.211				
1 1 1 81 82	0.398	0.149	0.209	1.53		
1 1 1 83 83	0.258	0.051	0.140	2.22		
1 1 1 84 84	0.257	0.051	0.140	2.22		
1 1 1 85 85	0.251	0.050	0.137	2.22		
1 1 1 86 86	0.303	0.058				
1 1 1 87 87	0.299	0.057				
1 1 1 88 88	0.290	0.056				
1 1 1 89 89	0.288	0.055				
1 1 1 90 90	0.200	0.019	0.040	2.13		
1 1 1 91 91	0.198	0.018	0.040	2.13		
1 1 1 92 92	0.197	0.018	0.040	2.13		
1 1 1 93 94	0.195	0.018	0.040	2.13		
1 1 1 95 99	0.169	0.011	0.022	8.90		
1 1 1 00 03	0.094	0.009	0.015	7.87	Includes LEV Sulfur Corr	1.36
1 1 1 04 50	0.094	0.009	0.015	7.87	Includes LEV Sulfur Corr	1.36
1 2 1 65 67	7.488	0.186			LDGT1	
1 2 1 68 69	4.576	0.258				
1 2 1 70 71	3.099	0.382				
1 2 1 72 74	3.470	0.176				
1 2 1 75 75	1.802	0.270				
1 2 1 76 76	1.813	0.272				
1 2 1 77 78	1.807	0.271				
1 2 1 79 80	0.876	0.282				
1 2 1 81 82	1.140	0.044	0.143	1.73		
1 2 1 83 83	1.156	0.045	0.145	1.73		
1 2 1 84 84	0.486	0.022	0.108	4.41		
1 2 1 85 85	0.483	0.022	0.107	4.41		
1 2 1 86 86	0.477	0.022	0.106	4.41		
1 2 1 87 87	0.487	0.022	0.108	4.41		
1 2 1 88 88	0.486	0.022	0.108	4.41		
1 2 1 89 89	0.491	0.022	0.109	4.41		
1 2 1 90 90	0.323	0.018	0.047	2.13		
1 2 1 91 91	0.306	0.017	0.044	2.13		
1 2 1 92 93	0.318	0.017	0.046	2.13		
1 2 1 94 94	0.317	0.017	0.046	2.13		
1 2 1 95 99	0.214	0.012	0.025	9.06		
1 2 1 00 03	0.110	0.008	0.016	8.29	Includes LEV Sulfur Corr	1.23
1 2 1 04 50	0.110	0.008	0.016	8.29	Includes LEV Sulfur Corr	1.23
1 3 1 65 69	9.885	0.186			LDGT2	
1 3 1 70 73	6.486	0.258				
1 3 1 74 78	6.486	0.176				
1 3 1 79 80	0.887	0.286				
1 3 1 81 82	1.139	0.044	0.143	1.73		
1 3 1 83 83	1.159	0.045	0.146	1.73		
1 3 1 84 84	0.492	0.022	0.109	4.41		
1 3 1 85 85	0.500	0.023	0.111	4.41		
1 3 1 86 86	0.509	0.023	0.113	4.41		
1 3 1 87 87	0.513	0.023	0.114	4.41		
1 3 1 88 88	0.508	0.023	0.113	4.41		
1 3 1 89 89	0.508	0.023	0.113	4.41		

1	3	1	90	90	0.340	0.019	0.049	2.13		
1	3	1	91	91	0.306	0.017	0.044	2.13		
1	3	1	92	93	0.318	0.017	0.046	2.13		
1	3	1	94	95	0.317	0.017	0.046	2.13		
1	3	1	96	96	0.318	0.017	0.046	2.13		
1	3	1	97	00	0.260	0.012	0.030	9.25		
1	3	1	01	03	0.258	0.012	0.030	9.25		
1	3	1	04	50	0.258	0.012	0.030	9.25		
1	4	1	94	94	0.586	0.037			HDGV	
1	4	1	95	95	0.586	0.037				
1	4	1	96	96	0.589	0.037				
1	4	1	97	97	0.589	0.037				
1	4	1	98	98	0.589	0.037				
1	4	1	99	99	0.589	0.037				
1	4	1	00	00	0.593	0.037				
1	4	1	01	01	0.593	0.037				
1	4	1	02	02	0.593	0.037				
1	4	1	03	03	0.593	0.037				
1	4	1	04	50	0.453	0.029				
1	5	1	95	95	0.161	0.011	0.021	8.90	LDDV	
1	5	1	96	96	0.161	0.011	0.021	8.90		
1	5	1	97	97	0.161	0.011	0.021	8.90		
1	5	1	98	98	0.161	0.011	0.021	8.90		
1	5	1	99	99	0.161	0.011	0.021	8.90		
1	5	1	00	00	0.066	0.006	0.011	7.87		
1	5	1	01	01	0.066	0.006	0.011	7.87		
1	5	1	02	02	0.066	0.006	0.011	7.87		
1	5	1	03	03	0.066	0.006	0.011	7.87		
1	5	1	04	50	0.066	0.006	0.011	7.87		
1	6	1	95	95	0.271	0.015	0.038	3.87	LDDT	Assumes 25% LDT1 and 75% LDT2
1	6	1	96	96	0.271	0.015	0.038	3.87		
1	6	1	97	97	0.231	0.011	0.027	9.21		
1	6	1	98	98	0.231	0.011	0.027	9.21		
1	6	1	99	99	0.231	0.011	0.027	9.21		
1	6	1	00	00	0.202	0.010	0.024	9.01		
1	6	1	01	01	0.202	0.010	0.024	9.01		
1	6	1	02	02	0.202	0.010	0.024	9.01		
1	6	1	03	03	0.202	0.010	0.024	9.01		
1	6	1	04	50	0.202	0.010	0.024	9.01		
1	7	1	94	03	0.320	0.000			HDDV	
1	7	1	04	50	0.290	0.000				

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TOG BERs - I/M OTR Control Case
0099            ZM    DR1    DR2 Flex Pt  File: OTR_IM_C.BER
1 1 1 65 67  7.488  0.186                       LDGV
1 1 1 68 69  4.576  0.258
1 1 1 70 71  3.099  0.382
1 1 1 72 74  3.491  0.165
1 1 1 75 75  1.068  0.282
1 1 1 76 77  1.071  0.283
1 1 1 78 79  1.074  0.284
1 1 1 80 80  0.371  0.211
1 1 1 81 82  0.398  0.149  0.209   1.53
1 1 1 83 83  0.258  0.051  0.140   2.22
1 1 1 84 84  0.257  0.051  0.140   2.22
1 1 1 85 85  0.251  0.050  0.137   2.22
1 1 1 86 86  0.303  0.058
1 1 1 87 87  0.299  0.057
1 1 1 88 88  0.290  0.056
1 1 1 89 89  0.288  0.055
1 1 1 90 90  0.200  0.019  0.040   2.13
1 1 1 91 91  0.198  0.018  0.040   2.13
1 1 1 92 92  0.197  0.018  0.040   2.13
1 1 1 93 94  0.195  0.018  0.040   2.13
1 1 1 95 99  0.169  0.011  0.022   8.90
1 1 1 00 03  0.094  0.009  0.015   7.87         Includes LEV Sulfur Corr    1.36
1 1 1 04 50  0.057  0.008  0.014   8.10         Includes LEV Sulfur Corr    1.36
1 2 1 65 67  7.488  0.186                       LDGT1
1 2 1 68 69  4.576  0.258
1 2 1 70 71  3.099  0.382
1 2 1 72 74  3.470  0.176
1 2 1 75 75  1.802  0.270
1 2 1 76 76  1.813  0.272
1 2 1 77 78  1.807  0.271
1 2 1 79 80  0.876  0.282
1 2 1 81 82  1.140  0.044  0.143   1.73
1 2 1 83 83  1.156  0.045  0.145   1.73
1 2 1 84 84  0.486  0.022  0.108   4.41
1 2 1 85 85  0.483  0.022  0.107   4.41
1 2 1 86 86  0.477  0.022  0.106   4.41
1 2 1 87 87  0.487  0.022  0.108   4.41
1 2 1 88 88  0.486  0.022  0.108   4.41
1 2 1 89 89  0.491  0.022  0.109   4.41
1 2 1 90 90  0.323  0.018  0.047   2.13
1 2 1 91 91  0.306  0.017  0.044   2.13
1 2 1 92 93  0.318  0.017  0.046   2.13
1 2 1 94 94  0.317  0.017  0.046   2.13
1 2 1 95 99  0.214  0.012  0.025   9.06
1 2 1 00 03  0.110  0.008  0.016   8.29         Includes LEV Sulfur Corr    1.23
1 2 1 04 50  0.058  0.008  0.014   8.10         Includes LEV Sulfur Corr    1.36
1 3 1 65 69  9.885  0.186                       LDGT2
1 3 1 70 73  6.486  0.258
1 3 1 74 78  6.486  0.176
1 3 1 79 80  0.887  0.286
1 3 1 81 82  1.139  0.044  0.143   1.73
1 3 1 83 83  1.159  0.045  0.146   1.73
1 3 1 84 84  0.492  0.022  0.109   4.41
1 3 1 85 85  0.500  0.023  0.111   4.41
1 3 1 86 86  0.509  0.023  0.113   4.41
1 3 1 87 87  0.513  0.023  0.114   4.41
1 3 1 88 88  0.508  0.023  0.113   4.41
1 3 1 89 89  0.508  0.023  0.113   4.41
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1	3	1	90	90	0.340	0.019	0.049	2.13		
1	3	1	91	91	0.306	0.017	0.044	2.13		
1	3	1	92	93	0.318	0.017	0.046	2.13		
1	3	1	94	95	0.317	0.017	0.046	2.13		
1	3	1	96	96	0.318	0.017	0.046	2.13		
1	3	1	97	00	0.260	0.012	0.030	9.25		
1	3	1	01	03	0.258	0.012	0.030	9.25		
1	3	1	04	50	0.058	0.008	0.014	8.10	Includes LEV Sulfur Corr	1.36
1	4	1	94	94	0.586	0.037			HDGV	
1	4	1	95	95	0.586	0.037				
1	4	1	96	96	0.589	0.037				
1	4	1	97	97	0.589	0.037				
1	4	1	98	98	0.589	0.037				
1	4	1	99	99	0.589	0.037				
1	4	1	00	00	0.593	0.037				
1	4	1	01	01	0.593	0.037				
1	4	1	02	02	0.593	0.037				
1	4	1	03	03	0.593	0.037				
1	4	1	04	50	0.453	0.029				
1	5	1	95	95	0.161	0.011	0.021	8.90	LDDV	
1	5	1	96	96	0.161	0.011	0.021	8.90		
1	5	1	97	97	0.161	0.011	0.021	8.90		
1	5	1	98	98	0.161	0.011	0.021	8.90		
1	5	1	99	99	0.161	0.011	0.021	8.90		
1	5	1	00	00	0.066	0.006	0.011	7.87		
1	5	1	01	01	0.066	0.006	0.011	7.87		
1	5	1	02	02	0.066	0.006	0.011	7.87		
1	5	1	03	03	0.066	0.006	0.011	7.87		
1	5	1	04	50	0.040	0.006	0.010	8.10		
1	6	1	95	95	0.271	0.015	0.038	3.87	LDDT	Assumes 25% LDT1 and 75% LDT2
1	6	1	96	96	0.271	0.015	0.038	3.87		
1	6	1	97	97	0.231	0.011	0.027	9.21		
1	6	1	98	98	0.231	0.011	0.027	9.21		
1	6	1	99	99	0.231	0.011	0.027	9.21		
1	6	1	00	00	0.202	0.010	0.024	9.01		
1	6	1	01	01	0.202	0.010	0.024	9.01		
1	6	1	02	02	0.202	0.010	0.024	9.01		
1	6	1	03	03	0.202	0.010	0.024	9.01		
1	6	1	04	50	0.040	0.006	0.010	8.10		
1	7	1	94	03	0.320	0.000			HDDV	
1	7	1	04	50	0.290	0.000				

TOG BERs - I/M Denver Baseline Case

0099					ZM	DR1	DR2	Flex Pt	File: DNV_IM_B.BER
2	1	1	65	67	9.660	0.186			LDGV
2	1	1	68	69	5.765	0.258			
2	1	1	70	71	4.741	0.382			
2	1	1	72	74	4.783	0.165			
2	1	1	75	75	2.029	0.282			
2	1	1	76	77	2.035	0.283			
2	1	1	78	79	2.042	0.284			
2	1	1	80	80	0.704	0.211			
2	1	1	81	82	0.485	0.149	0.209	1.53	
2	1	1	83	83	0.258	0.051	0.140	2.22	
2	1	1	84	84	0.257	0.051	0.140	2.22	
2	1	1	85	85	0.251	0.050	0.137	2.22	
2	1	1	86	86	0.303	0.058			
2	1	1	87	87	0.299	0.057			
2	1	1	88	88	0.290	0.056			
2	1	1	89	89	0.288	0.055			
2	1	1	90	90	0.200	0.019	0.040	2.13	
2	1	1	91	91	0.198	0.018	0.040	2.13	
2	1	1	92	92	0.197	0.018	0.040	2.13	
2	1	1	93	94	0.195	0.018	0.040	2.13	
2	1	1	95	00	0.169	0.011	0.022	8.90	
2	1	1	01	03	0.094	0.009	0.015	7.87	Includes LEV Sulfur Corr 1.36
2	1	1	04	50	0.094	0.009	0.015	7.87	Includes LEV Sulfur Corr 1.36
2	2	1	65	67	9.660	0.186			LDGT1
2	2	1	68	69	5.765	0.258			
2	2	1	70	71	4.741	0.382			
2	2	1	72	74	4.720	0.176			
2	2	1	75	75	3.423	0.270			
2	2	1	76	76	3.445	0.272			
2	2	1	77	78	3.434	0.271			
2	2	1	79	80	1.665	0.282			
2	2	1	81	82	2.166	0.044	0.143	1.73	
2	2	1	83	83	1.502	0.045	0.145	1.73	
2	2	1	84	84	0.729	0.022	0.108	4.41	
2	2	1	85	85	0.604	0.022	0.107	4.41	
2	2	1	86	86	0.596	0.022	0.106	4.41	
2	2	1	87	87	0.608	0.022	0.108	4.41	
2	2	1	88	88	0.608	0.022	0.108	4.41	
2	2	1	89	89	0.614	0.022	0.109	4.41	
2	2	1	90	90	0.403	0.018	0.047	2.13	
2	2	1	91	91	0.382	0.017	0.044	2.13	
2	2	1	92	93	0.398	0.017	0.046	2.13	
2	2	1	94	94	0.317	0.017	0.046	2.13	
2	2	1	95	00	0.214	0.012	0.025	9.06	
2	2	1	01	03	0.110	0.008	0.016	8.29	Includes LEV Sulfur Corr 1.23
2	2	1	04	50	0.110	0.008	0.016	8.29	Includes LEV Sulfur Corr 1.23
2	3	1	65	69	12.751	0.186			LDGT2
2	3	1	70	73	8.822	0.258			
2	3	1	74	78	8.822	0.176			
2	3	1	79	80	1.686	0.286			
2	3	1	81	82	1.480	0.044	0.143	1.73	
2	3	1	83	83	1.507	0.045	0.146	1.73	
2	3	1	84	84	0.738	0.022	0.109	4.41	
2	3	1	85	85	0.626	0.023	0.111	4.41	
2	3	1	86	86	0.636	0.023	0.113	4.41	
2	3	1	87	87	0.641	0.023	0.114	4.41	
2	3	1	88	88	0.635	0.023	0.113	4.41	
2	3	1	89	89	0.635	0.023	0.113	4.41	

2	3	1	90	90	0.425	0.019	0.049	2.13		
2	3	1	91	91	0.382	0.017	0.044	2.13		
2	3	1	92	93	0.398	0.017	0.046	2.13		
2	3	1	94	95	0.317	0.017	0.046	2.13		
2	3	1	96	96	0.318	0.017	0.046	2.13		
2	3	1	97	00	0.260	0.012	0.030	9.25		
2	3	1	01	03	0.258	0.012	0.030	9.25		
2	3	1	04	50	0.258	0.012	0.030	9.25		
2	4	1	94	94	0.996	0.037			HDGV	
2	4	1	95	95	0.996	0.037				
2	4	1	96	96	1.001	0.037				
2	4	1	97	97	1.001	0.037				
2	4	1	98	98	1.001	0.037				
2	4	1	99	99	1.001	0.037				
2	4	1	00	00	1.008	0.037				
2	4	1	01	01	1.008	0.037				
2	4	1	02	02	1.008	0.037				
2	4	1	03	03	1.008	0.037				
2	4	1	04	50	0.453	0.029				
2	5	1	95	95	0.161	0.011	0.021	8.90	LDDV	
2	5	1	96	96	0.161	0.011	0.021	8.90		
2	5	1	97	97	0.161	0.011	0.021	8.90		
2	5	1	98	98	0.161	0.011	0.021	8.90		
2	5	1	99	99	0.161	0.011	0.021	8.90		
2	5	1	00	00	0.161	0.011	0.021	8.90		
2	5	1	01	01	0.066	0.006	0.011	7.87		
2	5	1	02	02	0.066	0.006	0.011	7.87		
2	5	1	03	03	0.066	0.006	0.011	7.87		
2	5	1	04	50	0.066	0.006	0.011	7.87		
2	6	1	95	95	0.342	0.015	0.038	3.87	LDDT	Assumes 25% LDT1 and 75% LDT2
2	6	1	96	96	0.342	0.015	0.038	3.87		High Alt includes 1.26
2	6	1	97	97	0.291	0.011	0.027	9.21		correction to ZM
2	6	1	98	98	0.291	0.011	0.027	9.21		
2	6	1	99	99	0.291	0.011	0.027	9.21		
2	6	1	00	00	0.291	0.011	0.027	9.21		
2	6	1	01	01	0.255	0.010	0.024	9.01		
2	6	1	02	02	0.255	0.010	0.024	9.01		
2	6	1	03	03	0.255	0.010	0.024	9.01		
2	6	1	04	50	0.255	0.010	0.024	9.01		
2	7	1	94	03	0.735	0.000			HDDV	
2	7	1	04	50	0.668	0.000				

TOG BERs - I/M Denver Control Case

0099					ZM	DR1	DR2	Flex Pt	File:	DNV_IM_C.BER	
2	1	1	65	67	9.660	0.186				LDGV	
2	1	1	68	69	5.765	0.258					
2	1	1	70	71	4.741	0.382					
2	1	1	72	74	4.783	0.165					
2	1	1	75	75	2.029	0.282					
2	1	1	76	77	2.035	0.283					
2	1	1	78	79	2.042	0.284					
2	1	1	80	80	0.704	0.211					
2	1	1	81	82	0.485	0.149	0.209	1.53			
2	1	1	83	83	0.258	0.051	0.140	2.22			
2	1	1	84	84	0.257	0.051	0.140	2.22			
2	1	1	85	85	0.251	0.050	0.137	2.22			
2	1	1	86	86	0.303	0.058					
2	1	1	87	87	0.299	0.057					
2	1	1	88	88	0.290	0.056					
2	1	1	89	89	0.288	0.055					
2	1	1	90	90	0.200	0.019	0.040	2.13			
2	1	1	91	91	0.198	0.018	0.040	2.13			
2	1	1	92	92	0.197	0.018	0.040	2.13			
2	1	1	93	94	0.195	0.018	0.040	2.13			
2	1	1	95	00	0.169	0.011	0.022	8.90			
2	1	1	01	03	0.094	0.009	0.015	7.87		Includes LEV Sulfur Corr	1.36
2	1	1	04	50	0.057	0.008	0.014	8.10		Includes LEV Sulfur Corr	1.36
2	2	1	65	67	9.660	0.186				LDGT1	
2	2	1	68	69	5.765	0.258					
2	2	1	70	71	4.741	0.382					
2	2	1	72	74	4.720	0.176					
2	2	1	75	75	3.423	0.270					
2	2	1	76	76	3.445	0.272					
2	2	1	77	78	3.434	0.271					
2	2	1	79	80	1.665	0.282					
2	2	1	81	82	2.166	0.044	0.143	1.73			
2	2	1	83	83	1.502	0.045	0.145	1.73			
2	2	1	84	84	0.729	0.022	0.108	4.41			
2	2	1	85	85	0.604	0.022	0.107	4.41			
2	2	1	86	86	0.596	0.022	0.106	4.41			
2	2	1	87	87	0.608	0.022	0.108	4.41			
2	2	1	88	88	0.608	0.022	0.108	4.41			
2	2	1	89	89	0.614	0.022	0.109	4.41			
2	2	1	90	90	0.403	0.018	0.047	2.13			
2	2	1	91	91	0.382	0.017	0.044	2.13			
2	2	1	92	93	0.398	0.017	0.046	2.13			
2	2	1	94	94	0.317	0.017	0.046	2.13			
2	2	1	95	00	0.214	0.012	0.025	9.06			
2	2	1	01	03	0.110	0.008	0.016	8.29		Includes LEV Sulfur Corr	1.23
2	2	1	04	50	0.058	0.008	0.014	8.10		Includes LEV Sulfur Corr	1.36
2	3	1	65	69	12.751	0.186				LDGT2	
2	3	1	70	73	8.822	0.258					
2	3	1	74	78	8.822	0.176					
2	3	1	79	80	1.686	0.286					
2	3	1	81	82	1.480	0.044	0.143	1.73			
2	3	1	83	83	1.507	0.045	0.146	1.73			
2	3	1	84	84	0.738	0.022	0.109	4.41			
2	3	1	85	85	0.626	0.023	0.111	4.41			
2	3	1	86	86	0.636	0.023	0.113	4.41			
2	3	1	87	87	0.641	0.023	0.114	4.41			
2	3	1	88	88	0.635	0.023	0.113	4.41			
2	3	1	89	89	0.635	0.023	0.113	4.41			

2	3	1	90	90	0.425	0.019	0.049	2.13		
2	3	1	91	91	0.382	0.017	0.044	2.13		
2	3	1	92	93	0.398	0.017	0.046	2.13		
2	3	1	94	95	0.317	0.017	0.046	2.13		
2	3	1	96	96	0.318	0.017	0.046	2.13		
2	3	1	97	00	0.260	0.012	0.030	9.25		
2	3	1	01	03	0.258	0.012	0.030	9.25		
2	3	1	04	50	0.058	0.008	0.014	8.10	Includes LEV Sulfur Corr 1.36	
2	4	1	94	94	0.996	0.037			HDGV	
2	4	1	95	95	0.996	0.037				
2	4	1	96	96	1.001	0.037				
2	4	1	97	97	1.001	0.037				
2	4	1	98	98	1.001	0.037				
2	4	1	99	99	1.001	0.037				
2	4	1	00	00	1.008	0.037				
2	4	1	01	01	1.008	0.037				
2	4	1	02	02	1.008	0.037				
2	4	1	03	03	1.008	0.037				
2	4	1	04	50	0.453	0.029				
2	5	1	95	95	0.161	0.011	0.021	8.90	LDDV	
2	5	1	96	96	0.161	0.011	0.021	8.90		
2	5	1	97	97	0.161	0.011	0.021	8.90		
2	5	1	98	98	0.161	0.011	0.021	8.90		
2	5	1	99	99	0.161	0.011	0.021	8.90		
2	5	1	00	00	0.161	0.011	0.021	8.90		
2	5	1	01	01	0.066	0.006	0.011	7.87		
2	5	1	02	02	0.066	0.006	0.011	7.87		
2	5	1	03	03	0.066	0.006	0.011	7.87		
2	5	1	04	50	0.040	0.006	0.010	8.10		
2	6	1	95	95	0.342	0.015	0.038	3.87	LDDT	Assumes 25% LDT1 and 75% LDT2
2	6	1	96	96	0.342	0.015	0.038	3.87		High Alt includes 1.26
2	6	1	97	97	0.291	0.011	0.027	9.21		correction to ZM
2	6	1	98	98	0.291	0.011	0.027	9.21		for pre-2004 MY
2	6	1	99	99	0.291	0.011	0.027	9.21		
2	6	1	00	00	0.291	0.011	0.027	9.21		
2	6	1	01	01	0.255	0.010	0.024	9.01		
2	6	1	02	02	0.255	0.010	0.024	9.01		
2	6	1	03	03	0.255	0.010	0.024	9.01		
2	6	1	04	50	0.040	0.006	0.010	8.10		
2	7	1	94	03	0.735	0.000			HDDV	
2	7	1	04	50	0.668	0.000				

Off-Cycle Corrections - I/M 1990					UC/FTP Toxics Mass Fraction Ratios				
IV	MYA	MYB	AGG	A/C	BNZ	ACET	FORM	13BD	MTBE
1	1965	1965	1.079	1.016	1.000	1.000	1.000	1.000	1.000
1	1966	1966	1.079	1.016	1.000	1.000	1.000	1.000	1.000
1	1967	1967	1.078	1.015	1.000	1.000	1.000	1.000	1.000
1	1968	1968	1.090	1.018	1.000	1.000	1.000	1.000	1.000
1	1969	1969	1.089	1.017	1.000	1.000	1.000	1.000	1.000
1	1970	1970	1.081	1.016	1.000	1.000	1.000	1.000	1.000
1	1971	1971	1.081	1.016	1.000	1.000	1.000	1.000	1.000
1	1972	1972	1.122	1.023	1.000	1.000	1.000	1.000	1.000
1	1973	1973	1.120	1.023	1.000	1.000	1.000	1.000	1.000
1	1974	1974	1.118	1.023	1.000	1.000	1.000	1.000	1.000
1	1975	1975	1.137	1.026	1.000	1.000	1.000	1.000	1.000
1	1976	1976	1.137	1.026	1.000	1.000	1.000	1.000	1.000
1	1977	1977	1.136	1.026	1.000	1.000	1.000	1.000	1.000
1	1978	1978	1.135	1.026	1.000	1.000	1.000	1.000	1.000
1	1979	1979	1.135	1.025	1.000	1.000	1.000	1.000	1.000
1	1980	1980	1.211	1.037	1.000	1.000	1.000	1.000	1.000
1	1981	1981	1.230	1.040	1.126	0.919	0.894	0.708	0.965
1	1982	1982	1.230	1.040	1.128	0.920	0.897	0.712	0.963
1	1983	1983	1.230	1.040	1.156	0.935	0.936	0.760	0.943
1	1984	1984	1.230	1.040	1.165	0.940	0.949	0.776	0.936
1	1985	1985	1.230	1.040	1.175	0.945	0.964	0.793	0.929
1	1986	1986	1.230	1.040	1.213	0.966	1.018	0.860	0.900
1	1987	1987	1.230	1.040	1.228	0.973	1.039	0.885	0.890
1	1988	1988	1.230	1.040	1.247	0.983	1.066	0.918	0.876
1	1989	1989	1.230	1.040	1.273	0.997	1.103	0.963	0.856
1	1990	1990	1.230	1.040	1.315	1.020	1.163	1.037	0.825
1	1991	1991	1.230	1.040	1.315	1.020	1.163	1.037	0.825
1	1992	1992	1.230	1.040	1.315	1.020	1.163	1.037	0.825
1	1993	1993	1.230	1.040	1.315	1.020	1.163	1.037	0.825
1	1994	1994	1.230	1.040	1.315	1.020	1.163	1.037	0.825
1	1995	1995	1.290	1.010	1.315	1.020	1.163	1.037	0.825
1	1996	1996	1.290	1.010	1.315	1.020	1.163	1.037	0.825
1	1997	1997	1.290	1.010	1.315	1.020	1.163	1.037	0.825
1	1998	1998	1.290	1.010	1.315	1.020	1.163	1.037	0.825
1	1999	1999	1.290	1.010	1.315	1.020	1.163	1.037	0.825
1	2000	2000	1.290	1.010	1.315	1.020	1.163	1.037	0.825
1	2001	2001	1.220	1.003	1.315	1.020	1.163	1.037	0.825
1	2002	2002	1.150	0.995	1.315	1.020	1.163	1.037	0.825
1	2003	2003	1.052	0.985	1.315	1.020	1.163	1.037	0.825
1	2004	2050	1.010	0.980	1.315	1.020	1.163	1.037	0.825
2	1965	1965	1.048	1.002	1.000	1.000	1.000	1.000	1.000
2	1966	1966	1.048	1.002	1.000	1.000	1.000	1.000	1.000
2	1967	1967	1.048	1.002	1.000	1.000	1.000	1.000	1.000
2	1968	1968	1.055	1.003	1.000	1.000	1.000	1.000	1.000
2	1969	1969	1.055	1.003	1.000	1.000	1.000	1.000	1.000
2	1970	1970	1.050	1.003	1.000	1.000	1.000	1.000	1.000
2	1971	1971	1.050	1.003	1.000	1.000	1.000	1.000	1.000
2	1972	1972	1.074	1.004	1.000	1.000	1.000	1.000	1.000
2	1973	1973	1.074	1.004	1.000	1.000	1.000	1.000	1.000
2	1974	1974	1.073	1.004	1.000	1.000	1.000	1.000	1.000
2	1975	1975	1.078	1.004	1.000	1.000	1.000	1.000	1.000
2	1976	1976	1.078	1.004	1.000	1.000	1.000	1.000	1.000
2	1977	1977	1.077	1.004	1.000	1.000	1.000	1.000	1.000
2	1978	1978	1.077	1.004	1.000	1.000	1.000	1.000	1.000
2	1979	1979	1.091	1.004	1.000	1.000	1.000	1.000	1.000
2	1980	1980	1.091	1.004	1.000	1.000	1.000	1.000	1.000
2	1981	1981	1.258	1.011	1.126	0.919	0.894	0.708	0.965
2	1982	1982	1.249	1.011	1.128	0.920	0.897	0.712	0.963
2	1983	1983	1.238	1.010	1.156	0.935	0.936	0.760	0.943
2	1984	1984	1.230	1.010	1.167	0.941	0.953	0.780	0.934
2	1985	1985	1.230	1.010	1.177	0.946	0.967	0.797	0.927
2	1986	1986	1.230	1.010	1.193	0.955	0.989	0.824	0.915
2	1987	1987	1.230	1.010	1.211	0.965	1.015	0.856	0.902

2	1988	1988	1.230	1.010	1.216	0.967	1.022	0.864	0.899
2	1989	1989	1.230	1.010	1.219	0.968	1.026	0.869	0.896
2	1990	1990	1.230	1.010	1.284	1.003	1.118	0.982	0.848
2	1991	1991	1.230	1.010	1.315	1.020	1.163	1.037	0.825
2	1992	1992	1.230	1.010	1.315	1.020	1.163	1.037	0.825
2	1993	1993	1.230	1.010	1.315	1.020	1.163	1.037	0.825
2	1994	1994	1.230	1.010	1.315	1.020	1.163	1.037	0.825
2	1995	1995	1.290	1.010	1.315	1.020	1.163	1.037	0.825
2	1996	1996	1.290	1.010	1.315	1.020	1.163	1.037	0.825
2	1997	1997	1.290	1.010	1.315	1.020	1.163	1.037	0.825
2	1998	1998	1.290	1.010	1.315	1.020	1.163	1.037	0.825
2	1999	1999	1.290	1.010	1.315	1.020	1.163	1.037	0.825
2	2000	2000	1.290	1.010	1.315	1.020	1.163	1.037	0.825
2	2001	2001	1.223	1.008	1.315	1.020	1.163	1.037	0.825
2	2002	2002	1.155	1.005	1.315	1.020	1.163	1.037	0.825
2	2003	2003	1.061	1.002	1.315	1.020	1.163	1.037	0.825
2	2004	2050	1.020	1.000	1.315	1.020	1.163	1.037	0.825
3	1965	1965	1.044	0.998	1.000	1.000	1.000	1.000	1.000
3	1966	1966	1.044	0.998	1.000	1.000	1.000	1.000	1.000
3	1967	1967	1.044	0.998	1.000	1.000	1.000	1.000	1.000
3	1968	1968	1.043	0.998	1.000	1.000	1.000	1.000	1.000
3	1969	1969	1.042	0.998	1.000	1.000	1.000	1.000	1.000
3	1970	1970	1.048	0.998	1.000	1.000	1.000	1.000	1.000
3	1971	1971	1.047	0.998	1.000	1.000	1.000	1.000	1.000
3	1972	1972	1.047	0.998	1.000	1.000	1.000	1.000	1.000
3	1973	1973	1.046	0.998	1.000	1.000	1.000	1.000	1.000
3	1974	1974	1.052	0.997	1.000	1.000	1.000	1.000	1.000
3	1975	1975	1.051	0.997	1.000	1.000	1.000	1.000	1.000
3	1976	1976	1.050	0.997	1.000	1.000	1.000	1.000	1.000
3	1977	1977	1.048	0.998	1.000	1.000	1.000	1.000	1.000
3	1978	1978	1.047	0.998	1.000	1.000	1.000	1.000	1.000
3	1979	1979	1.090	0.996	1.000	1.000	1.000	1.000	1.000
3	1980	1980	1.091	0.996	1.000	1.000	1.000	1.000	1.000
3	1981	1981	1.264	0.989	1.126	0.919	0.894	0.708	0.965
3	1982	1982	1.253	0.989	1.128	0.920	0.897	0.712	0.963
3	1983	1983	1.241	0.990	1.156	0.935	0.936	0.760	0.943
3	1984	1984	1.230	0.990	1.166	0.940	0.951	0.778	0.935
3	1985	1985	1.230	0.990	1.177	0.946	0.966	0.796	0.927
3	1986	1986	1.230	0.990	1.193	0.955	0.990	0.825	0.915
3	1987	1987	1.230	0.990	1.212	0.965	1.016	0.857	0.902
3	1988	1988	1.230	0.990	1.216	0.967	1.022	0.865	0.898
3	1989	1989	1.230	0.990	1.219	0.969	1.026	0.869	0.896
3	1990	1990	1.230	0.990	1.284	1.003	1.118	0.982	0.848
3	1991	1991	1.230	0.990	1.315	1.020	1.163	1.037	0.825
3	1992	1992	1.230	0.990	1.315	1.020	1.163	1.037	0.825
3	1993	1993	1.230	0.990	1.315	1.020	1.163	1.037	0.825
3	1994	1994	1.230	0.990	1.315	1.020	1.163	1.037	0.825
3	1995	1995	1.230	0.990	1.315	1.020	1.163	1.037	0.825
3	1996	1996	1.230	0.990	1.315	1.020	1.163	1.037	0.825
3	1997	1997	1.290	1.000	1.315	1.020	1.163	1.037	0.825
3	1998	1998	1.290	1.000	1.315	1.020	1.163	1.037	0.825
3	1999	1999	1.290	1.000	1.315	1.020	1.163	1.037	0.825
3	2000	2000	1.290	1.000	1.315	1.020	1.163	1.037	0.825
3	2001	2001	1.290	1.000	1.315	1.020	1.163	1.037	0.825
3	2002	2002	1.190	1.000	1.315	1.020	1.163	1.037	0.825
3	2003	2003	1.090	1.000	1.315	1.020	1.163	1.037	0.825
3	2004	2050	1.040	1.000	1.315	1.020	1.163	1.037	0.825
4	1965	2050	1.000	1.000	1.000	1.000	1.000	1.000	1.000
5	1965	2050	1.000	1.000	1.000	1.000	1.000	1.000	1.000
6	1965	2050	1.000	1.000	1.000	1.000	1.000	1.000	1.000
7	1965	2050	1.000	1.000	1.000	1.000	1.000	1.000	1.000
8	1965	2050	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Off-Cycle Corrections - I/M 1996 a   UC/FTP Toxics Mass Fraction Ratios

IV	MYA	MYB	AGG	A/C	BNZ	ACET	FORM	13BD	MTBE
1	1965	1965	1.079	1.016	1.000	1.000	1.000	1.000	1.000
1	1966	1966	1.079	1.016	1.000	1.000	1.000	1.000	1.000
1	1967	1967	1.079	1.016	1.000	1.000	1.000	1.000	1.000
1	1968	1968	1.091	1.018	1.000	1.000	1.000	1.000	1.000
1	1969	1969	1.091	1.018	1.000	1.000	1.000	1.000	1.000
1	1970	1970	1.083	1.016	1.000	1.000	1.000	1.000	1.000
1	1971	1971	1.083	1.016	1.000	1.000	1.000	1.000	1.000
1	1972	1972	1.130	1.025	1.000	1.000	1.000	1.000	1.000
1	1973	1973	1.129	1.024	1.000	1.000	1.000	1.000	1.000
1	1974	1974	1.128	1.024	1.000	1.000	1.000	1.000	1.000
1	1975	1975	1.140	1.026	1.000	1.000	1.000	1.000	1.000
1	1976	1976	1.139	1.026	1.000	1.000	1.000	1.000	1.000
1	1977	1977	1.139	1.026	1.000	1.000	1.000	1.000	1.000
1	1978	1978	1.139	1.026	1.000	1.000	1.000	1.000	1.000
1	1979	1979	1.138	1.026	1.000	1.000	1.000	1.000	1.000
1	1980	1980	1.210	1.037	1.000	1.000	1.000	1.000	1.000
1	1981	1981	1.230	1.040	1.126	0.919	0.894	0.708	0.965
1	1982	1982	1.230	1.040	1.126	0.919	0.894	0.708	0.965
1	1983	1983	1.230	1.040	1.138	0.926	0.911	0.729	0.956
1	1984	1984	1.230	1.040	1.140	0.926	0.914	0.732	0.955
1	1985	1985	1.230	1.040	1.142	0.928	0.917	0.737	0.953
1	1986	1986	1.230	1.040	1.175	0.945	0.964	0.794	0.928
1	1987	1987	1.230	1.040	1.178	0.947	0.969	0.799	0.926
1	1988	1988	1.230	1.040	1.182	0.949	0.974	0.806	0.923
1	1989	1989	1.230	1.040	1.189	0.952	0.983	0.817	0.919
1	1990	1990	1.230	1.040	1.248	0.984	1.067	0.920	0.875
1	1991	1991	1.230	1.040	1.262	0.992	1.088	0.945	0.864
1	1992	1992	1.230	1.040	1.281	1.002	1.114	0.977	0.850
1	1993	1993	1.230	1.040	1.306	1.015	1.150	1.022	0.832
1	1994	1994	1.230	1.040	1.315	1.020	1.163	1.037	0.825
1	1995	1995	1.290	1.010	1.315	1.020	1.163	1.037	0.825
1	1996	1996	1.290	1.010	1.315	1.020	1.163	1.037	0.825
1	1997	1997	1.290	1.010	1.315	1.020	1.163	1.037	0.825
1	1998	1998	1.290	1.010	1.315	1.020	1.163	1.037	0.825
1	1999	1999	1.290	1.010	1.315	1.020	1.163	1.037	0.825
1	2000	2000	1.290	1.010	1.315	1.020	1.163	1.037	0.825
1	2001	2001	1.220	1.003	1.315	1.020	1.163	1.037	0.825
1	2002	2002	1.150	0.995	1.315	1.020	1.163	1.037	0.825
1	2003	2003	1.052	0.985	1.315	1.020	1.163	1.037	0.825
1	2004	2050	1.010	0.980	1.315	1.020	1.163	1.037	0.825
2	1965	1965	1.048	1.002	1.000	1.000	1.000	1.000	1.000
2	1966	1966	1.048	1.002	1.000	1.000	1.000	1.000	1.000
2	1967	1967	1.048	1.002	1.000	1.000	1.000	1.000	1.000
2	1968	1968	1.056	1.003	1.000	1.000	1.000	1.000	1.000
2	1969	1969	1.056	1.003	1.000	1.000	1.000	1.000	1.000
2	1970	1970	1.051	1.003	1.000	1.000	1.000	1.000	1.000
2	1971	1971	1.051	1.003	1.000	1.000	1.000	1.000	1.000
2	1972	1972	1.078	1.004	1.000	1.000	1.000	1.000	1.000
2	1973	1973	1.078	1.004	1.000	1.000	1.000	1.000	1.000
2	1974	1974	1.077	1.004	1.000	1.000	1.000	1.000	1.000
2	1975	1975	1.079	1.004	1.000	1.000	1.000	1.000	1.000
2	1976	1976	1.079	1.004	1.000	1.000	1.000	1.000	1.000
2	1977	1977	1.079	1.004	1.000	1.000	1.000	1.000	1.000
2	1978	1978	1.079	1.004	1.000	1.000	1.000	1.000	1.000
2	1979	1979	1.089	1.004	1.000	1.000	1.000	1.000	1.000
2	1980	1980	1.089	1.004	1.000	1.000	1.000	1.000	1.000
2	1981	1981	1.299	1.012	1.126	0.919	0.894	0.708	0.965
2	1982	1982	1.293	1.012	1.126	0.919	0.894	0.708	0.965
2	1983	1983	1.288	1.012	1.138	0.926	0.911	0.729	0.956
2	1984	1984	1.230	1.010	1.147	0.930	0.923	0.744	0.950
2	1985	1985	1.230	1.010	1.149	0.931	0.927	0.748	0.948
2	1986	1986	1.230	1.010	1.151	0.932	0.930	0.752	0.946
2	1987	1987	1.230	1.010	1.154	0.934	0.934	0.757	0.944

2	1988	1988	1.230	1.010	1.157	0.936	0.938	0.762	0.942
2	1989	1989	1.230	1.010	1.163	0.939	0.947	0.773	0.937
2	1990	1990	1.230	1.010	1.207	0.962	1.010	0.850	0.905
2	1991	1991	1.230	1.010	1.216	0.967	1.022	0.865	0.898
2	1992	1992	1.230	1.010	1.227	0.973	1.038	0.884	0.890
2	1993	1993	1.230	1.010	1.242	0.981	1.059	0.910	0.879
2	1994	1994	1.230	1.010	1.261	0.991	1.087	0.944	0.865
2	1995	1995	1.290	1.010	1.315	1.020	1.163	1.037	0.825
2	1996	1996	1.290	1.010	1.315	1.020	1.163	1.037	0.825
2	1997	1997	1.290	1.010	1.315	1.020	1.163	1.037	0.825
2	1998	1998	1.290	1.010	1.315	1.020	1.163	1.037	0.825
2	1999	1999	1.290	1.010	1.315	1.020	1.163	1.037	0.825
2	2000	2000	1.290	1.010	1.315	1.020	1.163	1.037	0.825
2	2001	2001	1.223	1.008	1.315	1.020	1.163	1.037	0.825
2	2002	2002	1.155	1.005	1.315	1.020	1.163	1.037	0.825
2	2003	2003	1.061	1.002	1.315	1.020	1.163	1.037	0.825
2	2004	2050	1.020	1.000	1.315	1.020	1.163	1.037	0.825
3	1965	1965	1.044	0.998	1.000	1.000	1.000	1.000	1.000
3	1966	1966	1.044	0.998	1.000	1.000	1.000	1.000	1.000
3	1967	1967	1.044	0.998	1.000	1.000	1.000	1.000	1.000
3	1968	1968	1.044	0.998	1.000	1.000	1.000	1.000	1.000
3	1969	1969	1.044	0.998	1.000	1.000	1.000	1.000	1.000
3	1970	1970	1.050	0.997	1.000	1.000	1.000	1.000	1.000
3	1971	1971	1.050	0.997	1.000	1.000	1.000	1.000	1.000
3	1972	1972	1.050	0.997	1.000	1.000	1.000	1.000	1.000
3	1973	1973	1.050	0.997	1.000	1.000	1.000	1.000	1.000
3	1974	1974	1.058	0.997	1.000	1.000	1.000	1.000	1.000
3	1975	1975	1.057	0.997	1.000	1.000	1.000	1.000	1.000
3	1976	1976	1.056	0.997	1.000	1.000	1.000	1.000	1.000
3	1977	1977	1.055	0.997	1.000	1.000	1.000	1.000	1.000
3	1978	1978	1.054	0.997	1.000	1.000	1.000	1.000	1.000
3	1979	1979	1.089	0.996	1.000	1.000	1.000	1.000	1.000
3	1980	1980	1.089	0.996	1.000	1.000	1.000	1.000	1.000
3	1981	1981	1.313	0.987	1.126	0.919	0.894	0.708	0.965
3	1982	1982	1.306	0.987	1.126	0.919	0.894	0.708	0.965
3	1983	1983	1.299	0.988	1.138	0.926	0.911	0.729	0.956
3	1984	1984	1.230	0.990	1.143	0.928	0.918	0.737	0.952
3	1985	1985	1.230	0.990	1.146	0.929	0.922	0.742	0.950
3	1986	1986	1.230	0.990	1.148	0.931	0.925	0.746	0.949
3	1987	1987	1.230	0.990	1.151	0.933	0.930	0.752	0.946
3	1988	1988	1.230	0.990	1.155	0.935	0.935	0.759	0.943
3	1989	1989	1.230	0.990	1.162	0.938	0.945	0.770	0.939
3	1990	1990	1.230	0.990	1.206	0.962	1.008	0.848	0.905
3	1991	1991	1.230	0.990	1.216	0.967	1.022	0.865	0.898
3	1992	1992	1.230	0.990	1.228	0.973	1.039	0.885	0.890
3	1993	1993	1.230	0.990	1.243	0.982	1.061	0.912	0.878
3	1994	1994	1.230	0.990	1.263	0.992	1.089	0.947	0.863
3	1995	1995	1.230	0.990	1.275	0.999	1.106	0.967	0.855
3	1996	1996	1.230	0.990	1.284	1.003	1.118	0.982	0.848
3	1997	1997	1.290	1.000	1.315	1.020	1.163	1.037	0.825
3	1998	1998	1.290	1.000	1.315	1.020	1.163	1.037	0.825
3	1999	1999	1.290	1.000	1.315	1.020	1.163	1.037	0.825
3	2000	2000	1.290	1.000	1.315	1.020	1.163	1.037	0.825
3	2001	2001	1.290	1.000	1.315	1.020	1.163	1.037	0.825
3	2002	2002	1.190	1.000	1.315	1.020	1.163	1.037	0.825
3	2003	2003	1.090	1.000	1.315	1.020	1.163	1.037	0.825
3	2004	2050	1.040	1.000	1.315	1.020	1.163	1.037	0.825
4	1965	2050	1.000	1.000	1.000	1.000	1.000	1.000	1.000
5	1965	2050	1.000	1.000	1.000	1.000	1.000	1.000	1.000
6	1965	2050	1.000	1.000	1.000	1.000	1.000	1.000	1.000
7	1965	2050	1.000	1.000	1.000	1.000	1.000	1.000	1.000
8	1965	2050	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Off-Cycle Corrections - Non-I/M 1990 UC/FTP Toxics Mass Fraction Ratios

IV	MYA	MYB	AGG	A/C	BNZ	ACET	FORM	13BD	MTBE
1	1965	1965	1.079	1.016	1.000	1.000	1.000	1.000	1.000
1	1966	1966	1.079	1.016	1.000	1.000	1.000	1.000	1.000
1	1967	1967	1.078	1.015	1.000	1.000	1.000	1.000	1.000
1	1968	1968	1.090	1.018	1.000	1.000	1.000	1.000	1.000
1	1969	1969	1.089	1.017	1.000	1.000	1.000	1.000	1.000
1	1970	1970	1.081	1.016	1.000	1.000	1.000	1.000	1.000
1	1971	1971	1.081	1.016	1.000	1.000	1.000	1.000	1.000
1	1972	1972	1.122	1.023	1.000	1.000	1.000	1.000	1.000
1	1973	1973	1.120	1.023	1.000	1.000	1.000	1.000	1.000
1	1974	1974	1.118	1.023	1.000	1.000	1.000	1.000	1.000
1	1975	1975	1.137	1.026	1.000	1.000	1.000	1.000	1.000
1	1976	1976	1.137	1.026	1.000	1.000	1.000	1.000	1.000
1	1977	1977	1.136	1.026	1.000	1.000	1.000	1.000	1.000
1	1978	1978	1.135	1.026	1.000	1.000	1.000	1.000	1.000
1	1979	1979	1.135	1.025	1.000	1.000	1.000	1.000	1.000
1	1980	1980	1.211	1.037	1.000	1.000	1.000	1.000	1.000
1	1981	1981	1.228	1.040	1.126	0.919	0.894	0.708	0.965
1	1982	1982	1.228	1.040	1.126	0.919	0.895	0.709	0.965
1	1983	1983	1.228	1.040	1.151	0.932	0.930	0.752	0.946
1	1984	1984	1.228	1.040	1.158	0.936	0.940	0.764	0.941
1	1985	1985	1.228	1.040	1.169	0.942	0.955	0.782	0.933
1	1986	1986	1.228	1.040	1.204	0.961	1.005	0.844	0.907
1	1987	1987	1.228	1.040	1.219	0.968	1.026	0.869	0.896
1	1988	1988	1.228	1.040	1.239	0.979	1.055	0.905	0.881
1	1989	1989	1.228	1.040	1.270	0.996	1.099	0.959	0.858
1	1990	1990	1.228	1.040	1.315	1.020	1.163	1.037	0.825
1	1991	1991	1.228	1.040	1.315	1.020	1.163	1.037	0.825
1	1992	1992	1.228	1.040	1.315	1.020	1.163	1.037	0.825
1	1993	1993	1.228	1.040	1.315	1.020	1.163	1.037	0.825
1	1994	1994	1.228	1.040	1.315	1.020	1.163	1.037	0.825
1	1995	1995	1.287	1.010	1.315	1.020	1.163	1.037	0.825
1	1996	1996	1.287	1.010	1.315	1.020	1.163	1.037	0.825
1	1997	1997	1.287	1.010	1.315	1.020	1.163	1.037	0.825
1	1998	1998	1.287	1.010	1.315	1.020	1.163	1.037	0.825
1	1999	1999	1.287	1.010	1.315	1.020	1.163	1.037	0.825
1	2000	2000	1.287	1.010	1.315	1.020	1.163	1.037	0.825
1	2001	2001	1.218	1.003	1.315	1.020	1.163	1.037	0.825
1	2002	2002	1.149	0.995	1.315	1.020	1.163	1.037	0.825
1	2003	2003	1.051	0.985	1.315	1.020	1.163	1.037	0.825
1	2004	2050	1.010	0.980	1.315	1.020	1.163	1.037	0.825
2	1965	1965	1.048	1.002	1.000	1.000	1.000	1.000	1.000
2	1966	1966	1.048	1.002	1.000	1.000	1.000	1.000	1.000
2	1967	1967	1.048	1.002	1.000	1.000	1.000	1.000	1.000
2	1968	1968	1.055	1.003	1.000	1.000	1.000	1.000	1.000
2	1969	1969	1.055	1.003	1.000	1.000	1.000	1.000	1.000
2	1970	1970	1.050	1.003	1.000	1.000	1.000	1.000	1.000
2	1971	1971	1.050	1.003	1.000	1.000	1.000	1.000	1.000
2	1972	1972	1.074	1.004	1.000	1.000	1.000	1.000	1.000
2	1973	1973	1.074	1.004	1.000	1.000	1.000	1.000	1.000
2	1974	1974	1.073	1.004	1.000	1.000	1.000	1.000	1.000
2	1975	1975	1.078	1.004	1.000	1.000	1.000	1.000	1.000
2	1976	1976	1.078	1.004	1.000	1.000	1.000	1.000	1.000
2	1977	1977	1.077	1.004	1.000	1.000	1.000	1.000	1.000
2	1978	1978	1.077	1.004	1.000	1.000	1.000	1.000	1.000
2	1979	1979	1.091	1.004	1.000	1.000	1.000	1.000	1.000
2	1980	1980	1.091	1.004	1.000	1.000	1.000	1.000	1.000
2	1981	1981	1.258	1.011	1.126	0.919	0.894	0.708	0.965
2	1982	1982	1.249	1.011	1.126	0.919	0.895	0.709	0.965
2	1983	1983	1.238	1.010	1.151	0.932	0.930	0.752	0.946
2	1984	1984	1.230	1.010	1.163	0.939	0.946	0.772	0.938
2	1985	1985	1.230	1.010	1.173	0.944	0.961	0.789	0.930
2	1986	1986	1.230	1.010	1.187	0.952	0.981	0.815	0.920
2	1987	1987	1.230	1.010	1.204	0.961	1.005	0.843	0.907

2	1988	1988	1.230	1.010	1.210	0.964	1.013	0.854	0.903
2	1989	1989	1.230	1.010	1.217	0.968	1.023	0.866	0.898
2	1990	1990	1.230	1.010	1.284	1.003	1.118	0.982	0.848
2	1991	1991	1.230	1.010	1.315	1.020	1.163	1.037	0.825
2	1992	1992	1.230	1.010	1.315	1.020	1.163	1.037	0.825
2	1993	1993	1.230	1.010	1.315	1.020	1.163	1.037	0.825
2	1994	1994	1.230	1.010	1.315	1.020	1.163	1.037	0.825
2	1995	1995	1.290	1.010	1.315	1.020	1.163	1.037	0.825
2	1996	1996	1.290	1.010	1.315	1.020	1.163	1.037	0.825
2	1997	1997	1.290	1.010	1.315	1.020	1.163	1.037	0.825
2	1998	1998	1.290	1.010	1.315	1.020	1.163	1.037	0.825
2	1999	1999	1.290	1.010	1.315	1.020	1.163	1.037	0.825
2	2000	2000	1.290	1.010	1.315	1.020	1.163	1.037	0.825
2	2001	2001	1.223	1.008	1.315	1.020	1.163	1.037	0.825
2	2002	2002	1.155	1.005	1.315	1.020	1.163	1.037	0.825
2	2003	2003	1.061	1.002	1.315	1.020	1.163	1.037	0.825
2	2004	2050	1.020	1.000	1.315	1.020	1.163	1.037	0.825
3	1965	1965	1.044	0.998	1.000	1.000	1.000	1.000	1.000
3	1966	1966	1.044	0.998	1.000	1.000	1.000	1.000	1.000
3	1967	1967	1.044	0.998	1.000	1.000	1.000	1.000	1.000
3	1968	1968	1.043	0.998	1.000	1.000	1.000	1.000	1.000
3	1969	1969	1.042	0.998	1.000	1.000	1.000	1.000	1.000
3	1970	1970	1.048	0.998	1.000	1.000	1.000	1.000	1.000
3	1971	1971	1.047	0.998	1.000	1.000	1.000	1.000	1.000
3	1972	1972	1.047	0.998	1.000	1.000	1.000	1.000	1.000
3	1973	1973	1.046	0.998	1.000	1.000	1.000	1.000	1.000
3	1974	1974	1.052	0.997	1.000	1.000	1.000	1.000	1.000
3	1975	1975	1.051	0.997	1.000	1.000	1.000	1.000	1.000
3	1976	1976	1.050	0.997	1.000	1.000	1.000	1.000	1.000
3	1977	1977	1.048	0.998	1.000	1.000	1.000	1.000	1.000
3	1978	1978	1.047	0.998	1.000	1.000	1.000	1.000	1.000
3	1979	1979	1.090	0.996	1.000	1.000	1.000	1.000	1.000
3	1980	1980	1.091	0.996	1.000	1.000	1.000	1.000	1.000
3	1981	1981	1.264	0.989	1.126	0.919	0.894	0.708	0.965
3	1982	1982	1.253	0.989	1.126	0.919	0.895	0.709	0.965
3	1983	1983	1.241	0.990	1.151	0.932	0.930	0.752	0.946
3	1984	1984	1.230	0.990	1.162	0.938	0.945	0.771	0.938
3	1985	1985	1.230	0.990	1.172	0.944	0.960	0.789	0.931
3	1986	1986	1.230	0.990	1.188	0.952	0.982	0.816	0.919
3	1987	1987	1.230	0.990	1.204	0.961	1.005	0.844	0.907
3	1988	1988	1.230	0.990	1.210	0.964	1.014	0.855	0.903
3	1989	1989	1.230	0.990	1.217	0.968	1.024	0.867	0.897
3	1990	1990	1.230	0.990	1.284	1.003	1.118	0.982	0.848
3	1991	1991	1.230	0.990	1.315	1.020	1.163	1.037	0.825
3	1992	1992	1.230	0.990	1.315	1.020	1.163	1.037	0.825
3	1993	1993	1.230	0.990	1.315	1.020	1.163	1.037	0.825
3	1994	1994	1.230	0.990	1.315	1.020	1.163	1.037	0.825
3	1995	1995	1.230	0.990	1.315	1.020	1.163	1.037	0.825
3	1996	1996	1.230	0.990	1.315	1.020	1.163	1.037	0.825
3	1997	1997	1.290	1.000	1.315	1.020	1.163	1.037	0.825
3	1998	1998	1.290	1.000	1.315	1.020	1.163	1.037	0.825
3	1999	1999	1.290	1.000	1.315	1.020	1.163	1.037	0.825
3	2000	2000	1.290	1.000	1.315	1.020	1.163	1.037	0.825
3	2001	2001	1.290	1.000	1.315	1.020	1.163	1.037	0.825
3	2002	2002	1.190	1.000	1.315	1.020	1.163	1.037	0.825
3	2003	2003	1.090	1.000	1.315	1.020	1.163	1.037	0.825
3	2004	2050	1.040	1.000	1.315	1.020	1.163	1.037	0.825
4	1965	2050	1.000	1.000	1.000	1.000	1.000	1.000	1.000
5	1965	2050	1.000	1.000	1.000	1.000	1.000	1.000	1.000
6	1965	2050	1.000	1.000	1.000	1.000	1.000	1.000	1.000
7	1965	2050	1.000	1.000	1.000	1.000	1.000	1.000	1.000
8	1965	2050	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Off-Cycle Corrections - Non-I/M 1996 UC/FTP Toxics Mass Fraction Ratios

IV	MYA	MYB	AGG	A/C	BNZ	ACET	FORM	13BD	MTBE
1	1965	1965	1.079	1.016	1.000	1.000	1.000	1.000	1.000
1	1966	1966	1.079	1.016	1.000	1.000	1.000	1.000	1.000
1	1967	1967	1.079	1.016	1.000	1.000	1.000	1.000	1.000
1	1968	1968	1.091	1.018	1.000	1.000	1.000	1.000	1.000
1	1969	1969	1.091	1.018	1.000	1.000	1.000	1.000	1.000
1	1970	1970	1.083	1.016	1.000	1.000	1.000	1.000	1.000
1	1971	1971	1.083	1.016	1.000	1.000	1.000	1.000	1.000
1	1972	1972	1.130	1.025	1.000	1.000	1.000	1.000	1.000
1	1973	1973	1.129	1.024	1.000	1.000	1.000	1.000	1.000
1	1974	1974	1.128	1.024	1.000	1.000	1.000	1.000	1.000
1	1975	1975	1.140	1.026	1.000	1.000	1.000	1.000	1.000
1	1976	1976	1.139	1.026	1.000	1.000	1.000	1.000	1.000
1	1977	1977	1.139	1.026	1.000	1.000	1.000	1.000	1.000
1	1978	1978	1.139	1.026	1.000	1.000	1.000	1.000	1.000
1	1979	1979	1.138	1.026	1.000	1.000	1.000	1.000	1.000
1	1980	1980	1.210	1.037	1.000	1.000	1.000	1.000	1.000
1	1981	1981	1.212	1.040	1.126	0.919	0.894	0.708	0.965
1	1982	1982	1.212	1.040	1.126	0.919	0.894	0.708	0.965
1	1983	1983	1.212	1.040	1.131	0.922	0.901	0.717	0.961
1	1984	1984	1.212	1.040	1.133	0.923	0.904	0.720	0.960
1	1985	1985	1.212	1.040	1.135	0.924	0.907	0.724	0.958
1	1986	1986	1.212	1.040	1.164	0.939	0.948	0.774	0.937
1	1987	1987	1.212	1.040	1.168	0.941	0.954	0.781	0.934
1	1988	1988	1.212	1.040	1.172	0.944	0.960	0.789	0.931
1	1989	1989	1.212	1.040	1.178	0.947	0.968	0.798	0.927
1	1990	1990	1.212	1.040	1.231	0.975	1.044	0.891	0.887
1	1991	1991	1.212	1.040	1.246	0.983	1.065	0.917	0.876
1	1992	1992	1.212	1.040	1.266	0.994	1.093	0.951	0.861
1	1993	1993	1.212	1.040	1.293	1.008	1.132	0.999	0.841
1	1994	1994	1.212	1.040	1.315	1.020	1.163	1.037	0.825
1	1995	1995	1.267	1.010	1.315	1.020	1.163	1.037	0.825
1	1996	1996	1.267	1.010	1.315	1.020	1.163	1.037	0.825
1	1997	1997	1.267	1.010	1.315	1.020	1.163	1.037	0.825
1	1998	1998	1.267	1.010	1.315	1.020	1.163	1.037	0.825
1	1999	1999	1.267	1.010	1.315	1.020	1.163	1.037	0.825
1	2000	2000	1.267	1.010	1.315	1.020	1.163	1.037	0.825
1	2001	2001	1.202	1.003	1.315	1.020	1.163	1.037	0.825
1	2002	2002	1.138	0.995	1.315	1.020	1.163	1.037	0.825
1	2003	2003	1.048	0.985	1.315	1.020	1.163	1.037	0.825
1	2004	2050	1.009	0.980	1.315	1.020	1.163	1.037	0.825
2	1965	1965	1.048	1.002	1.000	1.000	1.000	1.000	1.000
2	1966	1966	1.048	1.002	1.000	1.000	1.000	1.000	1.000
2	1967	1967	1.048	1.002	1.000	1.000	1.000	1.000	1.000
2	1968	1968	1.056	1.003	1.000	1.000	1.000	1.000	1.000
2	1969	1969	1.056	1.003	1.000	1.000	1.000	1.000	1.000
2	1970	1970	1.051	1.003	1.000	1.000	1.000	1.000	1.000
2	1971	1971	1.051	1.003	1.000	1.000	1.000	1.000	1.000
2	1972	1972	1.078	1.004	1.000	1.000	1.000	1.000	1.000
2	1973	1973	1.078	1.004	1.000	1.000	1.000	1.000	1.000
2	1974	1974	1.077	1.004	1.000	1.000	1.000	1.000	1.000
2	1975	1975	1.079	1.004	1.000	1.000	1.000	1.000	1.000
2	1976	1976	1.079	1.004	1.000	1.000	1.000	1.000	1.000
2	1977	1977	1.079	1.004	1.000	1.000	1.000	1.000	1.000
2	1978	1978	1.079	1.004	1.000	1.000	1.000	1.000	1.000
2	1979	1979	1.089	1.004	1.000	1.000	1.000	1.000	1.000
2	1980	1980	1.089	1.004	1.000	1.000	1.000	1.000	1.000
2	1981	1981	1.299	1.012	1.126	0.919	0.894	0.708	0.965
2	1982	1982	1.293	1.012	1.126	0.919	0.894	0.708	0.965
2	1983	1983	1.288	1.012	1.131	0.922	0.901	0.717	0.961
2	1984	1984	1.216	1.010	1.137	0.925	0.910	0.728	0.957
2	1985	1985	1.216	1.010	1.140	0.926	0.914	0.732	0.955
2	1986	1986	1.216	1.010	1.143	0.928	0.918	0.737	0.953
2	1987	1987	1.216	1.010	1.146	0.930	0.922	0.743	0.950

2	1988	1988	1.216	1.010	1.150	0.932	0.928	0.750	0.947
2	1989	1989	1.216	1.010	1.156	0.935	0.936	0.760	0.943
2	1990	1990	1.216	1.010	1.195	0.956	0.993	0.829	0.914
2	1991	1991	1.216	1.010	1.205	0.961	1.006	0.845	0.907
2	1992	1992	1.216	1.010	1.217	0.967	1.023	0.866	0.898
2	1993	1993	1.216	1.010	1.233	0.976	1.046	0.894	0.886
2	1994	1994	1.216	1.010	1.256	0.988	1.079	0.934	0.869
2	1995	1995	1.273	1.010	1.315	1.020	1.163	1.037	0.825
2	1996	1996	1.273	1.010	1.315	1.020	1.163	1.037	0.825
2	1997	1997	1.273	1.010	1.315	1.020	1.163	1.037	0.825
2	1998	1998	1.273	1.010	1.315	1.020	1.163	1.037	0.825
2	1999	1999	1.273	1.010	1.315	1.020	1.163	1.037	0.825
2	2000	2000	1.273	1.010	1.315	1.020	1.163	1.037	0.825
2	2001	2001	1.209	1.008	1.315	1.020	1.163	1.037	0.825
2	2002	2002	1.146	1.005	1.315	1.020	1.163	1.037	0.825
2	2003	2003	1.057	1.002	1.315	1.020	1.163	1.037	0.825
2	2004	2050	1.019	1.000	1.315	1.020	1.163	1.037	0.825
3	1965	1965	1.044	0.998	1.000	1.000	1.000	1.000	1.000
3	1966	1966	1.044	0.998	1.000	1.000	1.000	1.000	1.000
3	1967	1967	1.044	0.998	1.000	1.000	1.000	1.000	1.000
3	1968	1968	1.044	0.998	1.000	1.000	1.000	1.000	1.000
3	1969	1969	1.044	0.998	1.000	1.000	1.000	1.000	1.000
3	1970	1970	1.050	0.997	1.000	1.000	1.000	1.000	1.000
3	1971	1971	1.050	0.997	1.000	1.000	1.000	1.000	1.000
3	1972	1972	1.050	0.997	1.000	1.000	1.000	1.000	1.000
3	1973	1973	1.050	0.997	1.000	1.000	1.000	1.000	1.000
3	1974	1974	1.058	0.997	1.000	1.000	1.000	1.000	1.000
3	1975	1975	1.057	0.997	1.000	1.000	1.000	1.000	1.000
3	1976	1976	1.056	0.997	1.000	1.000	1.000	1.000	1.000
3	1977	1977	1.055	0.997	1.000	1.000	1.000	1.000	1.000
3	1978	1978	1.054	0.997	1.000	1.000	1.000	1.000	1.000
3	1979	1979	1.089	0.996	1.000	1.000	1.000	1.000	1.000
3	1980	1980	1.089	0.996	1.000	1.000	1.000	1.000	1.000
3	1981	1981	1.313	0.987	1.126	0.919	0.894	0.708	0.965
3	1982	1982	1.306	0.987	1.126	0.919	0.894	0.708	0.965
3	1983	1983	1.299	0.988	1.131	0.922	0.901	0.717	0.961
3	1984	1984	1.212	0.990	1.134	0.924	0.906	0.723	0.959
3	1985	1985	1.212	0.990	1.137	0.925	0.910	0.727	0.957
3	1986	1986	1.212	0.990	1.140	0.927	0.914	0.732	0.955
3	1987	1987	1.212	0.990	1.144	0.928	0.919	0.739	0.952
3	1988	1988	1.212	0.990	1.148	0.931	0.926	0.747	0.948
3	1989	1989	1.212	0.990	1.154	0.934	0.934	0.757	0.944
3	1990	1990	1.212	0.990	1.195	0.956	0.992	0.827	0.914
3	1991	1991	1.212	0.990	1.204	0.961	1.006	0.845	0.907
3	1992	1992	1.212	0.990	1.217	0.968	1.024	0.867	0.897
3	1993	1993	1.212	0.990	1.234	0.977	1.048	0.896	0.885
3	1994	1994	1.212	0.990	1.257	0.989	1.081	0.937	0.868
3	1995	1995	1.212	0.990	1.275	0.999	1.106	0.967	0.855
3	1996	1996	1.212	0.990	1.284	1.003	1.118	0.982	0.848
3	1997	1997	1.267	1.000	1.315	1.020	1.163	1.037	0.825
3	1998	1998	1.267	1.000	1.315	1.020	1.163	1.037	0.825
3	1999	1999	1.267	1.000	1.315	1.020	1.163	1.037	0.825
3	2000	2000	1.267	1.000	1.315	1.020	1.163	1.037	0.825
3	2001	2001	1.267	1.000	1.315	1.020	1.163	1.037	0.825
3	2002	2002	1.175	1.000	1.315	1.020	1.163	1.037	0.825
3	2003	2003	1.083	1.000	1.315	1.020	1.163	1.037	0.825
3	2004	2050	1.037	1.000	1.315	1.020	1.163	1.037	0.825
4	1965	2050	1.000	1.000	1.000	1.000	1.000	1.000	1.000
5	1965	2050	1.000	1.000	1.000	1.000	1.000	1.000	1.000
6	1965	2050	1.000	1.000	1.000	1.000	1.000	1.000	1.000
7	1965	2050	1.000	1.000	1.000	1.000	1.000	1.000	1.000
8	1965	2050	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Off-Cycle Corrections - Non-I/M 2007 UC/FTP Toxics Mass Fraction Ratios

IV	MYA	MYB	AGG	A/C	BNZ	ACET	FORM	13BD	MTBE
1	1965	1965	1.079	1.016	1.000	1.000	1.000	1.000	1.000
1	1966	1966	1.079	1.016	1.000	1.000	1.000	1.000	1.000
1	1967	1967	1.079	1.016	1.000	1.000	1.000	1.000	1.000
1	1968	1968	1.091	1.018	1.000	1.000	1.000	1.000	1.000
1	1969	1969	1.091	1.018	1.000	1.000	1.000	1.000	1.000
1	1970	1970	1.083	1.016	1.000	1.000	1.000	1.000	1.000
1	1971	1971	1.083	1.016	1.000	1.000	1.000	1.000	1.000
1	1972	1972	1.130	1.025	1.000	1.000	1.000	1.000	1.000
1	1973	1973	1.129	1.024	1.000	1.000	1.000	1.000	1.000
1	1974	1974	1.128	1.024	1.000	1.000	1.000	1.000	1.000
1	1975	1975	1.140	1.026	1.000	1.000	1.000	1.000	1.000
1	1976	1976	1.139	1.026	1.000	1.000	1.000	1.000	1.000
1	1977	1977	1.139	1.026	1.000	1.000	1.000	1.000	1.000
1	1978	1978	1.139	1.026	1.000	1.000	1.000	1.000	1.000
1	1979	1979	1.138	1.026	1.000	1.000	1.000	1.000	1.000
1	1980	1980	1.210	1.037	1.000	1.000	1.000	1.000	1.000
1	1981	1981	1.228	1.040	1.126	0.919	0.894	0.708	0.965
1	1982	1982	1.228	1.040	1.126	0.919	0.894	0.708	0.965
1	1983	1983	1.228	1.040	1.126	0.919	0.894	0.708	0.965
1	1984	1984	1.228	1.040	1.126	0.919	0.894	0.708	0.965
1	1985	1985	1.228	1.040	1.126	0.919	0.894	0.708	0.965
1	1986	1986	1.228	1.040	1.144	0.929	0.920	0.739	0.952
1	1987	1987	1.228	1.040	1.145	0.929	0.921	0.741	0.951
1	1988	1988	1.228	1.040	1.149	0.931	0.926	0.747	0.948
1	1989	1989	1.228	1.040	1.150	0.932	0.928	0.750	0.947
1	1990	1990	1.228	1.040	1.172	0.944	0.959	0.788	0.931
1	1991	1991	1.228	1.040	1.174	0.945	0.963	0.792	0.929
1	1992	1992	1.228	1.040	1.177	0.946	0.966	0.797	0.927
1	1993	1993	1.228	1.040	1.180	0.948	0.971	0.802	0.925
1	1994	1994	1.228	1.040	1.183	0.950	0.975	0.808	0.923
1	1995	1995	1.287	1.010	1.315	1.020	1.163	1.037	0.825
1	1996	1996	1.287	1.010	1.315	1.020	1.163	1.037	0.825
1	1997	1997	1.287	1.010	1.315	1.020	1.163	1.037	0.825
1	1998	1998	1.287	1.010	1.315	1.020	1.163	1.037	0.825
1	1999	1999	1.287	1.010	1.315	1.020	1.163	1.037	0.825
1	2000	2000	1.287	1.010	1.315	1.020	1.163	1.037	0.825
1	2001	2001	1.218	1.003	1.315	1.020	1.163	1.037	0.825
1	2002	2002	1.149	0.995	1.315	1.020	1.163	1.037	0.825
1	2003	2003	1.051	0.985	1.315	1.020	1.163	1.037	0.825
1	2004	2050	1.010	0.980	1.315	1.020	1.163	1.037	0.825
2	1965	1965	1.048	1.002	1.000	1.000	1.000	1.000	1.000
2	1966	1966	1.048	1.002	1.000	1.000	1.000	1.000	1.000
2	1967	1967	1.048	1.002	1.000	1.000	1.000	1.000	1.000
2	1968	1968	1.056	1.003	1.000	1.000	1.000	1.000	1.000
2	1969	1969	1.056	1.003	1.000	1.000	1.000	1.000	1.000
2	1970	1970	1.051	1.003	1.000	1.000	1.000	1.000	1.000
2	1971	1971	1.051	1.003	1.000	1.000	1.000	1.000	1.000
2	1972	1972	1.078	1.004	1.000	1.000	1.000	1.000	1.000
2	1973	1973	1.078	1.004	1.000	1.000	1.000	1.000	1.000
2	1974	1974	1.077	1.004	1.000	1.000	1.000	1.000	1.000
2	1975	1975	1.079	1.004	1.000	1.000	1.000	1.000	1.000
2	1976	1976	1.079	1.004	1.000	1.000	1.000	1.000	1.000
2	1977	1977	1.079	1.004	1.000	1.000	1.000	1.000	1.000
2	1978	1978	1.079	1.004	1.000	1.000	1.000	1.000	1.000
2	1979	1979	1.089	1.004	1.000	1.000	1.000	1.000	1.000
2	1980	1980	1.089	1.004	1.000	1.000	1.000	1.000	1.000
2	1981	1981	1.299	1.012	1.126	0.919	0.894	0.708	0.965
2	1982	1982	1.293	1.012	1.126	0.919	0.894	0.708	0.965
2	1983	1983	1.288	1.012	1.126	0.919	0.894	0.708	0.965
2	1984	1984	1.225	1.010	1.126	0.919	0.894	0.708	0.965
2	1985	1985	1.225	1.010	1.127	0.919	0.895	0.709	0.965
2	1986	1986	1.225	1.010	1.127	0.920	0.896	0.710	0.964
2	1987	1987	1.225	1.010	1.128	0.920	0.897	0.711	0.964

2	1988	1988	1.225	1.010	1.129	0.920	0.898	0.713	0.963
2	1989	1989	1.225	1.010	1.130	0.921	0.899	0.715	0.962
2	1990	1990	1.225	1.010	1.157	0.936	0.939	0.763	0.942
2	1991	1991	1.225	1.010	1.159	0.937	0.941	0.766	0.940
2	1992	1992	1.225	1.010	1.161	0.938	0.944	0.769	0.939
2	1993	1993	1.225	1.010	1.163	0.939	0.947	0.773	0.937
2	1994	1994	1.225	1.010	1.166	0.940	0.950	0.777	0.936
2	1995	1995	1.284	1.010	1.315	1.020	1.163	1.037	0.825
2	1996	1996	1.284	1.010	1.315	1.020	1.163	1.037	0.825
2	1997	1997	1.284	1.010	1.315	1.020	1.163	1.037	0.825
2	1998	1998	1.284	1.010	1.315	1.020	1.163	1.037	0.825
2	1999	1999	1.284	1.010	1.315	1.020	1.163	1.037	0.825
2	2000	2000	1.284	1.010	1.315	1.020	1.163	1.037	0.825
2	2001	2001	1.218	1.008	1.315	1.020	1.163	1.037	0.825
2	2002	2002	1.152	1.005	1.315	1.020	1.163	1.037	0.825
2	2003	2003	1.059	1.002	1.315	1.020	1.163	1.037	0.825
2	2004	2050	1.020	1.000	1.315	1.020	1.163	1.037	0.825
3	1965	1965	1.044	0.998	1.000	1.000	1.000	1.000	1.000
3	1966	1966	1.044	0.998	1.000	1.000	1.000	1.000	1.000
3	1967	1967	1.044	0.998	1.000	1.000	1.000	1.000	1.000
3	1968	1968	1.044	0.998	1.000	1.000	1.000	1.000	1.000
3	1969	1969	1.044	0.998	1.000	1.000	1.000	1.000	1.000
3	1970	1970	1.050	0.997	1.000	1.000	1.000	1.000	1.000
3	1971	1971	1.050	0.997	1.000	1.000	1.000	1.000	1.000
3	1972	1972	1.050	0.997	1.000	1.000	1.000	1.000	1.000
3	1973	1973	1.050	0.997	1.000	1.000	1.000	1.000	1.000
3	1974	1974	1.058	0.997	1.000	1.000	1.000	1.000	1.000
3	1975	1975	1.057	0.997	1.000	1.000	1.000	1.000	1.000
3	1976	1976	1.056	0.997	1.000	1.000	1.000	1.000	1.000
3	1977	1977	1.055	0.997	1.000	1.000	1.000	1.000	1.000
3	1978	1978	1.054	0.997	1.000	1.000	1.000	1.000	1.000
3	1979	1979	1.089	0.996	1.000	1.000	1.000	1.000	1.000
3	1980	1980	1.089	0.996	1.000	1.000	1.000	1.000	1.000
3	1981	1981	1.313	0.987	1.126	0.919	0.894	0.708	0.965
3	1982	1982	1.306	0.987	1.126	0.919	0.894	0.708	0.965
3	1983	1983	1.299	0.988	1.126	0.919	0.894	0.708	0.965
3	1984	1984	1.225	0.990	1.126	0.919	0.894	0.708	0.965
3	1985	1985	1.225	0.990	1.126	0.919	0.894	0.708	0.965
3	1986	1986	1.225	0.990	1.126	0.919	0.894	0.708	0.965
3	1987	1987	1.225	0.990	1.126	0.919	0.894	0.708	0.965
3	1988	1988	1.225	0.990	1.126	0.919	0.894	0.708	0.965
3	1989	1989	1.225	0.990	1.126	0.919	0.894	0.708	0.965
3	1990	1990	1.225	0.990	1.151	0.932	0.929	0.751	0.947
3	1991	1991	1.225	0.990	1.152	0.933	0.932	0.754	0.945
3	1992	1992	1.225	0.990	1.155	0.934	0.935	0.758	0.944
3	1993	1993	1.225	0.990	1.157	0.935	0.938	0.762	0.942
3	1994	1994	1.225	0.990	1.160	0.937	0.942	0.766	0.940
3	1995	1995	1.225	0.990	1.163	0.939	0.946	0.772	0.938
3	1996	1996	1.225	0.990	1.166	0.940	0.951	0.778	0.935
3	1997	1997	1.284	1.000	1.315	1.020	1.163	1.037	0.825
3	1998	1998	1.284	1.000	1.315	1.020	1.163	1.037	0.825
3	1999	1999	1.284	1.000	1.315	1.020	1.163	1.037	0.825
3	2000	2000	1.284	1.000	1.315	1.020	1.163	1.037	0.825
3	2001	2001	1.284	1.000	1.315	1.020	1.163	1.037	0.825
3	2002	2002	1.186	1.000	1.315	1.020	1.163	1.037	0.825
3	2003	2003	1.088	1.000	1.315	1.020	1.163	1.037	0.825
3	2004	2050	1.039	1.000	1.315	1.020	1.163	1.037	0.825
4	1965	2050	1.000	1.000	1.000	1.000	1.000	1.000	1.000
5	1965	2050	1.000	1.000	1.000	1.000	1.000	1.000	1.000
6	1965	2050	1.000	1.000	1.000	1.000	1.000	1.000	1.000
7	1965	2050	1.000	1.000	1.000	1.000	1.000	1.000	1.000
8	1965	2050	1.000	1.000	1.000	1.000	1.000	1.000	1.000

CO BERs - Non-I/M

0044					ZM	DR1	DR2	Flex Pt	File: BER_CO.PRN
1	1	2	65	67	78.270	2.250			LDGV
1	1	2	68	69	56.340	2.550			
1	1	2	70	71	42.170	3.130			
1	1	2	72	74	40.940	2.350			
1	1	2	75	79	17.720	2.460			
1	1	2	80	80	6.090	1.958			
1	1	2	81	81	4.301	2.441	3.037	1.50	
1	1	2	82	82	4.301	2.441	3.037	1.50	
1	1	2	83	83	2.813	0.191	1.650	2.16	
1	1	2	84	84	2.813	0.191	1.650	2.16	
1	1	2	85	85	2.813	0.191	1.650	2.16	
1	1	2	86	86	2.795	0.696			
1	1	2	87	87	2.795	0.696			
1	1	2	88	88	2.795	0.696			
1	1	2	89	89	2.795	0.696			
1	1	2	90	90	2.188	0.076	0.556	1.85	
1	1	2	91	91	2.188	0.076	0.556	1.85	
1	2	2	65	67	78.270	2.250			LDGT1
1	2	2	68	69	56.340	2.550			
1	2	2	70	71	42.170	3.130			
1	2	2	72	74	40.780	2.440			
1	2	2	75	78	24.550	2.590			
1	2	2	79	80	12.280	2.430			
1	2	2	81	83	14.503	1.929			
1	2	2	84	84	6.045	0.496	1.094	5.34	
1	2	2	85	85	6.045	0.496	1.094	5.34	
1	2	2	86	86	6.045	0.496	1.094	5.34	
1	2	2	87	87	6.045	0.496	1.094	5.34	
1	2	2	88	88	6.045	0.496	1.094	5.34	
1	2	2	89	89	6.045	0.496	1.094	5.34	
1	2	2	90	90	5.382	0.245	0.717	5.37	
1	2	2	91	91	5.382	0.245	0.717	5.37	
1	3	2	65	69	93.980	2.250			LDGT2
1	3	2	70	78	60.080	2.550			
1	3	2	79	80	12.280	2.430			
1	3	2	81	83	14.503	1.929			
1	3	2	84	84	6.045	0.496	1.094	5.34	
1	3	2	85	85	6.045	0.496	1.094	5.34	
1	3	2	86	86	6.045	0.496	1.094	5.34	
1	3	2	87	87	6.045	0.496	1.094	5.34	
1	3	2	88	88	6.045	0.496	1.094	5.34	
1	3	2	89	89	6.045	0.496	1.094	5.34	
1	3	2	90	90	5.382	0.245	0.717	5.37	
1	3	2	91	91	5.382	0.245	0.717	5.37	

Hi Alt CO BERs - Non-I/M

0033					ZM	DR1	DR2	Flex Pt	File: DNV_CO.PRN
1	1	2	81	81	16.815	2.441	3.037	1.50	LDGV
1	1	2	82	82	11.455	2.441	3.037	1.50	
1	1	2	83	83	2.839	0.191	1.650	2.16	
1	1	2	84	84	2.813	0.191	1.650	2.16	
1	1	2	85	85	2.813	0.191	1.650	2.16	
1	1	2	86	86	2.795	0.696			
1	1	2	87	87	2.795	0.696			
1	1	2	88	88	2.795	0.696			
1	1	2	89	89	2.795	0.696			
1	1	2	90	90	2.188	0.076	0.556	1.85	
1	1	2	91	91	2.188	0.076	0.556	1.85	
1	2	2	81	81	51.014	1.929			LDGT1
1	2	2	82	82	34.770	1.929			
1	2	2	83	83	34.770	1.929			
1	2	2	84	84	14.968	0.496	1.094	5.34	
1	2	2	85	85	8.462	0.496	1.094	5.34	
1	2	2	86	86	8.462	0.496	1.094	5.34	
1	2	2	87	87	8.463	0.496	1.094	5.34	
1	2	2	88	88	8.462	0.496	1.094	5.34	
1	2	2	89	89	8.461	0.496	1.094	5.34	
1	2	2	90	90	7.533	0.245	0.717	5.37	
1	2	2	91	91	7.532	0.245	0.717	5.37	
1	3	2	81	81	51.014	1.929			LDGT2
1	3	2	82	82	34.770	1.929			
1	3	2	83	83	34.770	1.929			
1	3	2	84	84	14.968	0.496	1.094	5.34	
1	3	2	85	85	8.462	0.496	1.094	5.34	
1	3	2	86	86	8.462	0.496	1.094	5.34	
1	3	2	87	87	8.463	0.496	1.094	5.34	
1	3	2	88	88	8.462	0.496	1.094	5.34	
1	3	2	89	89	8.461	0.496	1.094	5.34	
1	3	2	90	90	7.533	0.245	0.717	5.37	
1	3	2	91	91	7.532	0.245	0.717	5.37	

I/M	IV	MY	Agg Drv	A/C	
1	1	1965	1.328	1.217	Non-I/M Factors
1	1	1966	1.328	1.217	
1	1	1967	1.324	1.215	
1	1	1968	1.370	1.237	
1	1	1969	1.365	1.235	
1	1	1970	1.375	1.240	
1	1	1971	1.371	1.238	
1	1	1972	1.432	1.265	
1	1	1973	1.426	1.263	
1	1	1974	1.419	1.260	
1	1	1975	1.574	1.321	
1	1	1976	1.568	1.319	
1	1	1977	1.560	1.316	
1	1	1978	1.552	1.313	
1	1	1979	1.543	1.310	
1	1	1980	1.861	1.407	
1	1	1981	1.611	1.326	
1	1	1982	1.611	1.326	
1	1	1983	1.611	1.326	
1	1	1984	1.611	1.326	
1	1	1985	1.611	1.326	
1	1	1986	1.611	1.326	
1	1	1987	1.611	1.326	
1	1	1988	1.611	1.326	
1	1	1989	1.611	1.326	
1	1	1990	1.611	1.326	
1	1	1991	1.611	1.326	
1	2	1965	1.328	1.217	
1	2	1966	1.328	1.217	
1	2	1967	1.324	1.215	
1	2	1968	1.370	1.237	
1	2	1969	1.365	1.235	
1	2	1970	1.375	1.240	
1	2	1971	1.371	1.238	
1	2	1972	1.432	1.265	
1	2	1973	1.426	1.263	
1	2	1974	1.419	1.260	
1	2	1975	1.574	1.321	
1	2	1976	1.568	1.319	
1	2	1977	1.560	1.316	
1	2	1978	1.552	1.313	
1	2	1979	1.543	1.310	
1	2	1980	1.292	1.158	
1	2	1981	1.318	1.169	
1	2	1982	1.316	1.168	
1	2	1983	1.314	1.167	
1	2	1984	1.617	1.267	
1	2	1985	1.617	1.267	
1	2	1986	1.617	1.267	

1	2	1987	1.617	1.267	
1	2	1988	1.617	1.267	
1	2	1989	1.617	1.267	
1	2	1990	1.617	1.267	
1	2	1991	1.617	1.267	
1	3	1965	1.125	1.069	
1	3	1966	1.125	1.069	
1	3	1967	1.124	1.068	
1	3	1968	1.123	1.068	
1	3	1969	1.121	1.067	
1	3	1970	1.152	1.082	
1	3	1971	1.151	1.081	
1	3	1972	1.149	1.081	
1	3	1973	1.147	1.080	
1	3	1974	1.148	1.080	
1	3	1975	1.146	1.079	
1	3	1976	1.144	1.078	
1	3	1977	1.141	1.077	
1	3	1978	1.138	1.075	
1	3	1979	1.292	1.140	
1	3	1980	1.292	1.140	
1	3	1981	1.320	1.150	
1	3	1982	1.317	1.150	
1	3	1983	1.314	1.148	
1	3	1984	1.617	1.238	
1	3	1985	1.617	1.238	
1	3	1986	1.617	1.238	
1	3	1987	1.617	1.238	
1	3	1988	1.617	1.238	
1	3	1989	1.617	1.238	
1	3	1990	1.617	1.238	
1	3	1991	1.617	1.238	
2	1	1965	1.328	1.217	I/M Factors
2	1	1966	1.328	1.217	
2	1	1967	1.324	1.215	
2	1	1968	1.370	1.237	
2	1	1969	1.365	1.235	
2	1	1970	1.375	1.240	
2	1	1971	1.371	1.238	
2	1	1972	1.432	1.265	
2	1	1973	1.426	1.263	
2	1	1974	1.419	1.260	
2	1	1975	1.574	1.321	
2	1	1976	1.568	1.319	
2	1	1977	1.560	1.316	
2	1	1978	1.552	1.313	
2	1	1979	1.543	1.310	
2	1	1980	1.861	1.407	
2	1	1981	1.630	1.340	
2	1	1982	1.630	1.340	

2	1	1983	1.630	1.340
2	1	1984	1.630	1.340
2	1	1985	1.630	1.340
2	1	1986	1.630	1.340
2	1	1987	1.630	1.340
2	1	1988	1.630	1.340
2	1	1989	1.630	1.340
2	1	1990	1.630	1.340
2	1	1991	1.630	1.340
2	2	1965	1.328	1.217
2	2	1966	1.328	1.217
2	2	1967	1.324	1.215
2	2	1968	1.370	1.237
2	2	1969	1.365	1.235
2	2	1970	1.375	1.240
2	2	1971	1.371	1.238
2	2	1972	1.432	1.265
2	2	1973	1.426	1.263
2	2	1974	1.419	1.260
2	2	1975	1.574	1.321
2	2	1976	1.568	1.319
2	2	1977	1.560	1.316
2	2	1978	1.552	1.313
2	2	1979	1.543	1.310
2	2	1980	1.292	1.158
2	2	1981	1.318	1.169
2	2	1982	1.316	1.168
2	2	1983	1.314	1.167
2	2	1984	1.630	1.270
2	2	1985	1.630	1.270
2	2	1986	1.630	1.270
2	2	1987	1.630	1.270
2	2	1988	1.630	1.270
2	2	1989	1.630	1.270
2	2	1990	1.630	1.270
2	2	1991	1.630	1.270
2	3	1965	1.125	1.069
2	3	1966	1.125	1.069
2	3	1967	1.124	1.068
2	3	1968	1.123	1.068
2	3	1969	1.121	1.067
2	3	1970	1.152	1.082
2	3	1971	1.151	1.081
2	3	1972	1.149	1.081
2	3	1973	1.147	1.080
2	3	1974	1.148	1.080
2	3	1975	1.146	1.079
2	3	1976	1.144	1.078
2	3	1977	1.141	1.077
2	3	1978	1.138	1.075

2	3	1979	1.292	1.140
2	3	1980	1.292	1.140
2	3	1981	1.320	1.150
2	3	1982	1.317	1.150
2	3	1983	1.314	1.148
2	3	1984	1.630	1.240
2	3	1985	1.630	1.240
2	3	1986	1.630	1.240
2	3	1987	1.630	1.240
2	3	1988	1.630	1.240
2	3	1989	1.630	1.240
2	3	1990	1.630	1.240
2	3	1991	1.630	1.240

			Malf	Functioning Systems	
MY	LDGV	LDGT	Rate	LDGV	LDGT
1965	0.60	0.29	0.050	0.570	0.276
1966	0.60	0.29	0.050	0.570	0.276
1967	0.60	0.29	0.050	0.570	0.276
1968	0.60	0.29	0.050	0.570	0.276
1969	0.60	0.29	0.050	0.570	0.276
1970	0.60	0.29	0.050	0.570	0.276
1971	0.60	0.29	0.050	0.570	0.276
1972	0.60	0.29	0.050	0.570	0.276
1973	0.65	0.29	0.038	0.626	0.279
1974	0.65	0.29	0.038	0.626	0.279
1975	0.65	0.29	0.038	0.626	0.279
1976	0.65	0.29	0.038	0.626	0.279
1977	0.65	0.35	0.038	0.626	0.337
1978	0.65	0.35	0.025	0.634	0.341
1979	0.65	0.35	0.025	0.634	0.341
1980	0.65	0.35	0.025	0.634	0.341
1981	0.67	0.39	0.025	0.655	0.382
1982	0.69	0.43	0.025	0.677	0.423
1983	0.72	0.48	0.010	0.709	0.471
1984	0.74	0.52	0.009	0.732	0.513
1985	0.76	0.56	0.008	0.754	0.556
1986	0.78	0.60	0.006	0.777	0.598
1987	0.80	0.64	0.005	0.800	0.641
1988	0.83	0.69	0.000	0.826	0.686
1989	0.85	0.73	0.000	0.848	0.728
1990	0.87	0.77	0.000	0.870	0.770
1991	0.87	0.77	0.000	0.870	0.770

Oxygenated Fuels Benefits (% Red per 1 wt % Oxygen)

		Normals		Highs	
IV	MY	% Red	g/mi	% Red	g/mi
1	1981	0.0552	4.9	0.0645	20.5
1	1982	0.0576	4.9	0.0663	20.5
1	1983	0.0532	4.9	0.0630	20.5
1	1984	0.0431	4.9	0.0554	20.5
1	1985	0.0441	4.9	0.0561	20.5
1	1986	0.0535	3.2	0.0540	20.5
1	1987	0.0532	3.2	0.0537	20.5
1	1988	0.0375	3.0	0.0530	20.5
1	1989	0.0375	3.0	0.0530	20.5
1	1990	0.0336	2.8	0.0530	20.5
1	1991	0.0336	2.8	0.0530	20.5
1	1992	0.0310	2.8	0.0530	20.5
1	1993	0.0310	2.8	0.0530	20.5
1	1994	0.0186	2.2	0.0530	20.5
1	1995	0.0062	1.7	0.0530	20.5
1	1996	0.0000	1.4	0.0530	20.5
1	1997	0.0000	1.4	0.0530	20.5
1	1998	0.0000	1.4	0.0530	20.5
1	1999	0.0000	1.4	0.0530	20.5
1	2000	0.0000	1.4	0.0530	20.5
1	2001	0.0000	0.9	0.0530	20.5
1	2002	0.0000	0.9	0.0530	20.5
1	2003	0.0000	0.9	0.0530	20.5
1	2004	0.0000	0.9	0.0530	20.5
1	2005	0.0000	0.9	0.0530	20.5
1	2006	0.0000	0.9	0.0530	20.5
1	2007	0.0000	0.9	0.0530	20.5
1	2008	0.0000	0.9	0.0530	20.5
1	2009	0.0000	0.9	0.0530	20.5
1	2010	0.0000	0.9	0.0530	20.5
2	1981	0.0913	4.9	0.0920	20.5
2	1982	0.0918	4.9	0.0924	20.5
2	1983	0.0854	4.9	0.0874	20.5
2	1984	0.0793	4.9	0.0828	20.5
2	1985	0.0667	4.9	0.0733	20.5
2	1986	0.0668	3.2	0.0638	20.5
2	1987	0.0589	3.2	0.0551	20.5
2	1988	0.0575	3.2	0.0536	20.5
2	1989	0.0574	3.2	0.0535	20.5
2	1990	0.0570	3.2	0.0530	20.5
2	1991	0.0570	3.2	0.0530	20.5
2	1992	0.0310	2.8	0.0530	20.5

2	1993	0.0310	2.8	0.0530	20.5
2	1994	0.0186	2.2	0.0530	20.5
2	1995	0.0062	1.7	0.0530	20.5
2	1996	0.0000	1.4	0.0530	20.5
2	1997	0.0000	1.4	0.0530	20.5
2	1998	0.0000	1.4	0.0530	20.5
2	1999	0.0000	1.4	0.0530	20.5
2	2000	0.0000	1.4	0.0530	20.5
2	2001	0.0000	0.9	0.0530	20.5
2	2002	0.0000	0.9	0.0530	20.5
2	2003	0.0000	0.9	0.0530	20.5
2	2004	0.0000	0.9	0.0530	20.5
2	2005	0.0000	0.9	0.0530	20.5
2	2006	0.0000	0.9	0.0530	20.5
2	2007	0.0000	0.9	0.0530	20.5
2	2008	0.0000	0.9	0.0530	20.5
2	2009	0.0000	0.9	0.0530	20.5
2	2010	0.0000	0.9	0.0530	20.5
3	1981	0.0913	4.9	0.0920	20.5
3	1982	0.0918	4.9	0.0924	20.5
3	1983	0.0854	4.9	0.0874	20.5
3	1984	0.0793	4.9	0.0828	20.5
3	1985	0.0667	4.9	0.0733	20.5
3	1986	0.0668	3.2	0.0638	20.5
3	1987	0.0589	3.2	0.0551	20.5
3	1988	0.0575	3.2	0.0536	20.5
3	1989	0.0574	3.2	0.0535	20.5
3	1990	0.0570	3.2	0.0530	20.5
3	1991	0.0570	3.2	0.0530	20.5
3	1992	0.0310	2.8	0.0530	20.5
3	1993	0.0310	2.8	0.0530	20.5
3	1994	0.0310	2.8	0.0530	20.5
3	1995	0.0310	2.8	0.0530	20.5
3	1996	0.0186	2.2	0.0530	20.5
3	1997	0.0062	1.7	0.0530	20.5
3	1998	0.0000	1.4	0.0530	20.5
3	1999	0.0000	1.4	0.0530	20.5
3	2000	0.0000	1.4	0.0530	20.5
3	2001	0.0000	1.4	0.0530	20.5
3	2002	0.0000	1.4	0.0530	20.5
3	2003	0.0000	1.4	0.0530	20.5
3	2004	0.0000	1.4	0.0530	20.5
3	2005	0.0000	1.4	0.0530	20.5
3	2006	0.0000	1.4	0.0530	20.5
3	2007	0.0000	1.4	0.0530	20.5
3	2008	0.0000	1.4	0.0530	20.5

3	2009	0.0000	1.4	0.0530	20.5
3	2010	0.0000	1.4	0.0530	20.5

Appendix B

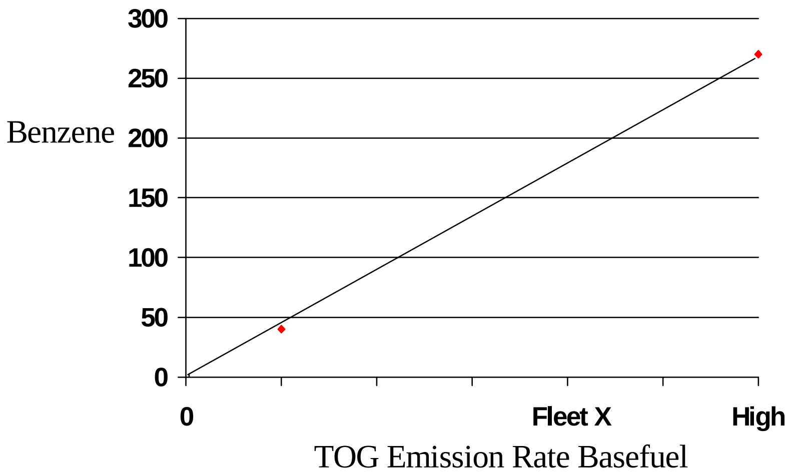
Methodology to Account for Normal/High Emitter Distributions in T2ATTOX (Development of Toxic-TOG Curves)

Modeling Toxics to Account for Normal/High Emitter Distributions in T2ATTOX

1) Complex Model gives benzene emission rate at normal and high emission levels

2) Figure below relates benzene gram per mile to TOG gram per mile

3) Case: MY cohort fleet with FTP $TOG_{Basefuel}$ = X (X is calculated within MOBILE)



4) Assume: This fleet is a mix of

$$N_H = \frac{X - FTP\ TOG_{NormalBasefuel}}{FTP\ TOG_{HighBasefuel} - FTP\ TOG_{NormalBasefuel}}\ X\ 100\ \%$$

$$N_N = \frac{FTP\ TOG_{HighBasefuel} - X}{FTP\ TOG_{HighBasefuel} - FTP\ TOG_{NormalBasefuel}}\ X\ 100\ \%$$

5) Question: What is the fleet's benzene on fuel F1?

Answer:

$$\frac{N_H\ X\ Bz_{HighFuelF1} + N_N\ X\ Bz_{Normal\ FuelF1}}{N_H + N_N = 1}$$

$$= (\frac{X - FTP\ TOG_N}{FTP\ TOG_H - FTP\ TOG_N})\ X\ (Bz_{H\ F1}) + (\frac{FTP\ TOG_H - X}{FTP\ TOG_H - FTP\ TOG_N})\ X\ (Bz_{N\ F1})$$

$$= (\frac{FTP\ TOG_H\ X\ Bz_{N\ F1} - FTP\ TOG_N\ X\ Bz_{H\ F1}}{FTP\ TOG_H - FTP\ TOG_N} + (\frac{Bz_H - Bz_N}{FTP\ TOG_H - FTP\ TOG_N}) * X$$

$$= A_{F1\ Tech1} + B_{F1\ Tech1} * X$$

(Mass emission rate of benzene on Fuel F1, including the effect of fuel F1 on TOG)

$$Bz\ \% = \frac{A + B * X}{X}$$

6) Inside MOBILE5b:

- No fleet ought to be cleaner than TOG FTP_N or dirtier than TOG FTP_H
- If base fuel is not indolene, need to be sure commercial fuel adjustment is applied before X is used with A and B
- I/M adjustment happens before toxic number calculated
- Other adjustments (non-FTP -- speed, temp, etc.) have to come after A and B are applied

7) For non-complex model technology types:

$$A = 0$$

$$B = (k_X) * \left(\frac{VOC_{Fuel\ X}}{VOC_{Fuel\ Baseline}}\right)$$

Appendix C

Equations Used to Generate Toxics Fractions for Non-Complex Model Vehicles

Non-Catalyst and Oxidation Catalyst LDGVs, LDGT1, LDGT2s
All Heavy-Duty Gasoline Vehicles and Motorcycles
All Diesel Vehicles

Exhaust Toxic Fraction Equations for LDGV with Oxidation Catalysts, Non-Catalyst LDGV, HDGV, LDDV and HDDV

Table 1 presents equations for estimating exhaust toxic fractions for light-duty gasoline vehicles with oxidation catalysts, light duty non-catalyst gasoline vehicles, heavy duty gasoline vehicles, and heavy duty diesel vehicles. Exhaust benzene, 1,3-butadiene, formaldehyde, and acetaldehyde fractions for light duty gasoline vehicles with three-way catalysts and three-way plus oxidation catalysts, as well as evaporative benzene fractions for all catalyst technologies and vehicle classes, will be estimated using the Complex Model.

Benzene

For LDGVs with no catalyst or an oxidation catalyst, and for HDGVs with no catalyst, the equation used was:

$$Bz\%THC = (0.8551*(\text{volume \% benzene}) + 0.12198*(\text{volume \% aromatics}) - 1.1626)$$

For HDGVs with three-way catalysts, the equation used was:

$$Bz\%THC = 1.077 + 0.7732*(\text{volume \% benzene}) + 0.0987*(\text{volume \% aromatics} - \text{volume \% benzene})$$

These equations were used in the "Motor Vehicle-Related Air Toxics Study" (EPA, 1993) and were originally developed for the draft Regulatory Impact Analysis for RVP regulations (EPA, 1987). The benzene/TOG fractions for LDDVs, LDDTs, and HDDVs in Table 1 were based on analysis of available speciation data (Springer, 1977; Springer, 1979; Bass and Newkirk, 1995; CE-CERT, 1998).

Formaldehyde

Formaldehyde/TOG fractions for vehicles running on baseline gasoline and diesels were based on analysis of available speciation data (see attachment). The TOG fraction for LDGVs/LDGTs with oxidation catalysts, running on baseline fuel, was based on data from fifty vehicles tested in eleven studies (Urban, 1980a; Springer, 1979; Sigsby et al., 1987; Smith, 1981; Stump et al., 1989, 1990, 1994, 1996; Auto/Oil, 1990; Boekhaus et al., 1991; Warner-Selph and Smith, 1991; Colorado Department of Health, 1987). The TOG fraction for LDGVs/LDGTs without catalysts, running on baseline fuel, was based on data from sixteen vehicles tested in five studies (Urban, 1981, Urban 1980a, Sigsby et al., 1987, Warner-Selph and Smith, 1991, Stump et. al, unpublished). The LDDV fraction was based on data from seven vehicles tested in two studies (Springer, 1977; Springer, 1979). The HDDV fraction were based on data from four engines in three studies (Springer, 1979; Bass and Newkirk, 1995; CE-CERT, 1998). The fraction for HDGVs without catalysts was based on data from two engines in two studies (Springer, 1979; Bass and Newkirk, 1995). The three-way fraction for HDGVs was based on data from one engine in one study (Bass and Newkirk, 1995).

To calculate TOG fractions for vehicles running on MTBE blends and gasohol, adjustment factors were applied to the baseline emission fractions for each vehicle class/catalyst combination based on average percent change. The adjustment factors were obtained by comparing data from vehicles running on baseline gasoline to data from the same vehicles running on oxygenated gasoline. For MTBE, change was defined by solving the equation:

$$\text{TOG frac @ 0\% MTBE} * (1 + (\text{change}/2.7) * \text{Ox}) = \text{TOG frac @ 15\% MTBE}$$

For ethanol, change was defined by solving the equation:

$$\text{TOG frac @ 0\% EtOH} * (1 + (\text{change}/3.5) * \text{Ox}) = \text{TOG frac @ 10\% EtOH}$$

The data used to develop the change estimates are provided in the attachment.

Data from five vehicles in three studies were used to develop the MTBE change estimate for LDGVs/LDGTs with oxidation catalysts (Auto/Oil, 1990; Boekhaus et al., 1991; Stump et al., 1994). Data from two vehicles in two studies were used to develop the MTBE change estimate for LDGVs/LDGTs without catalysts (Warner-Selph and Smith, 1991; Stump, 1997). Data from one vehicle was used to develop the MTBE change estimate for non-catalyst HDGVs (Bass and Newkirk, 1995). For catalyst-equipped HDGVs, the MTBE change estimate for LDGVs with three-way catalysts from the EPA document, "Motor Vehicle-Related Air Toxics Study" was used as a surrogate (EPA, 1993).

For ethanol, data from ten vehicles in three studies were used to develop the change estimate for LDGVs/LDGTs with oxidation catalysts (Warner-Selph and Smith, 1991; Colorado Department of Health, 1987; Stump et al., 1996). Data from five vehicles in two studies were used to develop the ethanol change estimate for LDGVs/LDGTs/HDGVs without catalysts (Warner-Selph and Smith, 1991; Colorado Department of Health, 1987). For catalyst-equipped HDGVs, the ethanol change estimate for LDGVs with three-way catalysts from the EPA document, "Motor Vehicle-Related Air Toxics Study" was used as a surrogate (EPA, 1993).

Acetaldehyde

Acetaldehyde/TOG fractions for vehicles running on baseline gasoline and diesels were based on analysis of the same speciation data used for formaldehyde (see attachment). The adjustment factors for MTBE blends and gasohol were also obtained using the same equations and data that were used for formaldehyde.

1,3-Butadiene

1,3-butadiene/TOG fractions for vehicles running on baseline gasoline and diesels were based on analysis of available speciation data (see attachment). The TOG fraction for LDGVs/LDGTs with oxidation catalysts, running on baseline fuel, was based on data from fifty vehicles tested in ten studies (Urban, 1980a; Springer, 1979; Sigsby et al., 1987; Smith, 1981; Stump et al., 1989, 1990, 1994, 1996; Auto/Oil, 1990; Boekhaus et al., 1991; Warner-Selph and Smith, 1991; CARB, 1991). The TOG fraction for LDGVs/LDGTs without catalysts, running on baseline fuel, was based on data from eighteen vehicles tested in three studies (CARB, 1991; Stump, 1997; Warner-Selph and Smith, 1991). The LDDV fraction was based on data from two vehicles tested in one study (CARB, 1991). The HDDV fraction was based on data from three engines in three studies (CARB, 1991; Bass and Newkirk, 1995; CE-CERT, 1998). The fraction for HDGVs without catalysts and HDGVs with catalysts were both based on data from one engine in one study (Bass and Newkirk, 1995).

The adjustment factors were also obtained using the same equations and data that were used for formaldehyde and acetaldehyde, with one exception. The adjustment factor for formaldehyde and acetaldehyde with an MTBE blend uses a change estimate from LDGVs with three-way catalysts as a surrogate. However, for 1,3-butadiene, the estimate is based on data from one vehicle in one study (Bass and Newkirk, 1995).

MTBE

MTBE/TOG fractions were based on available speciation data. These data were from vehicles running on fuels with varying levels of MTBE. To obtain an average 15% MTBE fraction across studies for a given vehicle class/technology group, an assumption was made that the relationship between MTBE in the fuel and exhaust was linear. MTBE/TOG fractions from vehicles running on a blend with X percent MTBE were adjusted to represent the emission fractions for a 15% by volume blend as follows:

TOG frac @ 15% MTBE = TOG frac @ X% MTBE * (2.7 / wt. % oxygen)

The resultant MTBE emission fractions for a 15% blend were used to develop the equations in Table 1.

Data from five vehicles in three studies were used to develop the 15% MTBE emission fraction for LDGVs/LDGTs with oxidation catalysts (Auto/Oil, 1990; Boekhaus et al., 1991; Stump et al., 1994). Data from one vehicle was used to develop the fraction for LDGVs/LDGTs without catalysts (Warner-Selph and Smith, 1991), the fraction for non-catalyst HDGVs (Bass and Newkirk, 1995), and the fraction for HDGVs with catalysts (Bass and Newkirk, 1995).

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Vehicle Class/ Catalyst	Baseline Gasoline	MTBE Gasoline	EtOH Gasoline
<u>Benzene</u>			
LDGV/oxcat	Bz % TOG = 0.8551* (vol. % Bz) + 0.12198 * (vol. % Arom.) - 1.1626[1]	Bz % TOG = 0.8551* (vol. % Bz) + 0.12198 * (vol. % Arom.) - 1.1626	Bz % TOG = 0.8551* (vol. % Bz) + 0.12198 * (vol. % Arom.) - 1.1626
LDGV/noncat	Bz % TOG = 0.8551* (vol. % Bz) + 0.12198 * (vol. % Arom.) - 1.1626[2]	Bz % TOG = 0.8551* (vol. % Bz) + 0.12198 * (vol. % Arom.) - 1.1626	Bz % TOG = 0.8551* (vol. % Bz) + 0.12198 * (vol. % Arom.) - 1.1626
HDGV/noncat	Bz % TOG = 0.8551* (vol. % Bz) + 0.12198 * (vol. % Arom.) - 1.1626[3]	Bz % TOG = 0.8551* (vol. % Bz) + 0.12198 * (vol. % Arom.) - 1.1626	Bz % TOG = 0.8551* (vol. % Bz) + 0.12198 * (vol. % Arom.) - 1.1626
HDGV/cat	Bz%TOG = 1.077 + 0.7732*(volume % benzene) + 0.0987 * (volume % aromatics - volume % benzene)[4]	Bz%TOG = 1.077 + 0.7732*(volume % benzene) + 0.0987 * (volume % aromatics - volume % benzene)	Bz%TOG = 1.077 + 0.7732*(volume % benzene) + 0.0987 * (volume % aromatics - volume % benzene)
LDDV	Bz % TOG = 0.0200		

[1]From 1993 EPA Report, "Motor Vehicle-Related Air Toxics Study," EPA 420-R-93-005.

[2]From 1993 EPA Report, "Motor Vehicle-Related Air Toxics Study," EPA 420-R-93-005.

[3]From 1993 EPA Report, "Motor Vehicle-Related Air Toxics Study," EPA 420-R-93-005.

[4]From 1993 EPA Report, "Motor Vehicle-Related Air Toxics Study," EPA 420-R-93-005.

Vehicle Class/ Catalyst	Baseline Gasoline	MTBE Gasoline	EtOH Gasoline
LDDT	Bz % TOG = 0.0200		
HDDV	Bz % TOG = 0.0105		
Formaldehyde			
LDGV/oxcat	Form % TOG = 0.0151	Form % TOG = 0.0151 + ((0.0151 * 1.2082)*(wt % MTBE/2.7))	Form % TOG = 0.0151 + ((0.0151 * 0.3350)*(wt % EtOH/3.5))
LDGV/noncat	Form % TOG = 0.0224	Form % TOG = 0.0224 + ((0.0224 * 0.4336)*(wt % MTBE/2.7))	Form % TOG = 0.0224 + ((0.0224 * 0.1034)*(wt % EtOH/3.5))
HDGV/noncat	Form % TOG = 0.0347	Form % TOG = 0.0347 + ((0.0347 * 0.1259)*(wt % MTBE/2.7))	Form % TOG = 0.0347 + ((0.0347 * 0.1034)*(wt % EtOH/3.5))
HDGV/cat	Form % TOG = 0.0054	Form % TOG = 0.0054 + ((0.0054 * 0.6746)*(wt % MTBE/2.7))[5]	Form % TOG = 0.0054 + ((0.0054 * 0.4758)*(wt % EtOH/3.5))[6]
LDDV	Form % TOG = 0.0386		
LDDT	Form % TOG = 0.0386		
HDDV	Form % TOG = 0.0782		

[5] Change with oxygenate estimate, 0.6746, from 3-way catalyst LDGV estimate in Appendix B4 of 1993 EPA Report, "Motor Vehicle-Related Air Toxics Study," EPA 420-R-93-005.

[6] Change with oxygenate estimate, 0.4758, from 3-way catalyst LDGV estimate in Appendix B4 of 1993 EPA Report, "Motor Vehicle-Related Air Toxics Study," EPA 420-R-93-005.

Vehicle Class/ Catalyst	**Baseline Gasoline**	**MTBE Gasoline**	**EtOH Gasoline**
<u>Acetaldehyde</u>			
LDGV/oxcat	Acet % TOG = 0.0047	Acet % TOG = 0.0047 + ((0.0047 * 0.2556)*(wt % MTBE/2.7))	Acet % TOG = 0.0047 + ((0.0047 * 2.1074)*(wt % EtOH/3.5))
LDGV/noncat	Acet % TOG = 0.0060	Acet % TOG = 0.0060 + ((0.0060 * 0.2303)*(wt % MTBE/2.7))	Acet % TOG = 0.0060 + ((0.0060 * 1.1445)*(wt % EtOH/3.5))
HDGV/noncat	Acet % TOG = 0.0067	Acet % TOG = 0.0067	Acet % TOG = 0.0067 + ((0.0067 * 1.1445)*(wt % EtOH/3.5))
HDGV/cat	Acet % TOG = 0.0005	Acet % TOG = 0.0005 + ((0.0005 * 0.0826)*(wt % MTBE/2.7))[7]	Acet % TOG = 0.0005 + ((0.0005 * 1.1369)*(wt % EtOH/3.5))[8]
LDDV	Acet % TOG = 0.0123		
LDDT	Acet % TOG = 0.0123		
HDDV	Acet % TOG = 0.0288		

[7]Change with oxygenate estimate, 0.0826, from 3-way catalyst LDGV estimate in Appendix B4 of 1993 EPA Report, "Motor Vehicle-Related Air Toxics Study," EPA 420-R-93-005.

[8]Change with oxygenate estimate, 1.1369, from 3-way catalyst LDGV estimate in Appendix B4 of 1993 EPA Report, "Motor Vehicle-Related Air Toxics Study," EPA 420-R-93-005.

Vehicle Class/ Catalyst	Baseline Gasoline	MTBE Gasoline	EtOH Gasoline
<u>1,3-Butadiene</u>			
LDGV/oxcat	Buta % TOG = 0.0044	Buta % TOG = 0.0044 + ((0.0044 * -0.2227)*(wt % MTBE/2.7))	Buta % TOG = 0.0044 + ((0.0044* -0.2804)*(wt % EtOH/3.5))
LDGV/noncat	Buta % TOG = 0.0092	Buta % TOG = 0.0092 + ((0.0092 * 0.1517)*(wt % MTBE/2.7))	Buta % TOG = 0.0092 + ((0.0092 * 0.1233)*(wt % EtOH/3.5))
HDGV/noncat	Buta % TOG = 0.0074	Buta % TOG = 0.0074 + ((0.0074 * -0.2172)*(wt % MTBE/2.7))	Buta % TOG = 0.0074 + ((0.0074 * 0.1233)*(wt % MTBE/2.7))
HDGV/cat	Buta % TOG = 0.0029	Buta % TOG = 0.0029 + ((0.0029 * -0.3233)*(wt % MTBE/2.7))	Buta % TOG = 0.0029 + ((0.0029 * -0.1188)*(wt % EtOH/3.5))[9]
LDDV	Buta % TOG = 0.0090		
LDDT	Buta % TOG = 0.0090		
HDDV	Buta % TOG = 0.0061		

[9]Change with oxygenate estimate, -0.1188, from 3-way catalyst LDGV estimate in Appendix B4 of 1993 EPA Report, "Motor Vehicle-Related Air Toxics Study," EPA 420-R-93-005.

Vehicle Class/ Catalyst	Baseline Gasoline	MTBE Gasoline	EtOH Gasoline
<u>MTBE</u>			
LDGV/oxcat		MTBE % TOG = 0.0464*(wt % MTBE/2.7)	
LDGV/noncat		MTBE % TOG = 0.0333*(wt % MTBE/2.7)	
HDGV/noncat		MTBE % TOG = 0.0209*(wt % MTBE/2.7)	
HDGV/cat		MTBE % TOG = 0.0155*(wt % MTBE/2.7)	

Appendix D

EPA's Suggested Methodology to Determine Toxics Fuel Effects from the Complex Model

(fuelsum6.wpd)

Toxics Fuel Effects Summary

I. Pre-1981 vehicles

A. Technology description: These vehicles include open-loop noncatalyst vehicles (through 1974) and open-loop vehicles equipped with oxidation catalysts (1975-1980 cars and trucks).

B. Fuel effect quantification

Baseline VOC emissions are derived from T2AT. The effects of fuel changes on exhaust VOC emissions from these vehicles are taken from Greg Janssen's July 31, 1991 memo and are summarized below.

VOC Emission Effects

Fuel parameter	Non-catalyst vehicles	Oxidation catalyst vehicles
Oxygen, per 1 wt%	- 1.6%	- 4.46
RVP, per 1 psi	+ 1.8%	+ 1.7%

To convert VOC FTP emissions to toxics emissions, Rich Cook has developed mass fraction equations that describe toxics as a function of at most one or two fuel properties.

Off-cycle VOC emissions are modeled in T2AT as an additive factor to FTP emissions. These emissions may have different toxics fractions than on-cycle emissions do. To model these emissions, the CARB database should be used to develop off-cycle toxics fractions using one of two approaches: If available, data from open-loop non-catalyst or oxidation catalyst cars should be used to develop off-cycle toxics fractions. Otherwise, assume the same proportional change in toxics fractions as was observed for more modern vehicles in the CARB database.

The CARB Predictive Model is not a viable option for these vehicles because CARB has repudiated its earlier analysis of fuel effects on emissions from pre-1981 cars.

II. 1981-1983 Vehicles

A. Technology description: These vehicles fall into 3 classes: open-loop vehicles equipped with oxidation catalysts, open-loop vehicles equipped with three-way plus oxidation catalysts, and closed-loop vehicles. The latter class includes vehicles with a range of fuel distribution systems and both three-way and three-way plus oxidation catalysts. A small fraction of trucks have no controls.

B. Fuel effect quantification

1. Non-catalyst and open-loop oxidation catalyst vehicles: The equations developed by Rich Cook can be used.

2. Open-loop vehicles with three-way + oxidation catalysts: These vehicles will be modeled as open-loop vehicles with oxidation catalysts. The three-way catalyst is primarily used to control NOx. Furthermore, in the absence of closed-loop controls, the efficacy of the three-way catalyst on older vehicles (all such vehicles will be at least 5 years old in 1990 and 11 years old in 1996) is questionable.

3. Closed-loop vehicles: The appropriate complex model technology types can be used. The relationship between vehicle technologies and Complex Model technology types is summarized below.

Technology	**Complex Model Tech Types**
Carbureted (3-way and 3-way+oxcat)	9
3-way PFI	Simple average of 1, 2, 5
3-way TBI	Simple average of 3 & 6
3-way+oxcat PFI	4
3-way+oxcat TBI	7
Higher emitters (all technologies)	Higher emitter

Off-cycle VOC emissions are modeled in T2AT as an additive factor to FTP emissions. These emissions may have different toxics fractions than on-cycle emissions do. To model these emissions, the CARB database should be used to develop off-cycle toxics fractions using one of two approaches: If available, data from cars with the corresponding vehicle technology should be used to develop off-cycle toxics fractions. Otherwise, assume the same proportional change in toxics fractions as was observed for more modern vehicles in the CARB database.

The CARB Predictive Model is not a viable option for these vehicles because the CARB model does not distinguish between normal and higher emitters. It also is not designed to account for tech group to tech group variations, which can be large (two-fold or even more).

C. Caveats

These vehicles are not equipped with adaptive learning, whereas the vehicles tested for the Complex Model all had adaptive learning. Using Complex Model fuel effects to represent the effect of fuel changes on emissions will tend to underestimate the benefits of oxygenates in particular; it may also underestimate the impact of RVP on exhaust emissions.

D. Additional work: Adjust tech group-specific emissions to account for tech group to tech group variations in baseline VOC and toxics emissions, as described in Appendix A.

III. 1984-1985 cars, 1984-1987 trucks

A. Technology description: These vehicles are dominated by closed-loop technologies without adaptive learning. They include a small percentage of open-loop cars equipped with three-way plus oxidation catalysts and a few open-loop trucks with oxidation catalysts, but they are dominated by closed-loop vehicles. The latter class includes vehicles with a range of fuel distribution systems and both three-way and three-way plus oxidation catalysts.

B. Fuel effect quantification

1. Open-loop vehicles: The same approach described for earlier open-loop vehicles should be followed.

2. Closed-loop vehicles: The appropriate complex model technology types can be used. The relationship between vehicle technologies and Complex Model technology types is summarized below.

Technology	Complex Model Tech Types
Carbureted (3-way and 3-way+oxcat)	9
3-way PFI	Simple average of 1, 2, 5
3-way TBI	Simple average of 3 & 6
3-way+oxcat PFI	4
3-way+oxcat TBI	7
Higher emitters (all technologies)	Higher emitter

The CARB Predictive Model is not a viable option for these vehicles because the CARB model does not distinguish between normal and higher emitters. It also is not designed to account for tech group to tech group variations, which can be large (two-fold or even more).

3. Off-cycle adjustments: T2AT uses a multiplicative adjustment factor to account for off-cycle adjustments for these and later vehicles. Toxics fractions will have to be modified to account for the different toxics fractions observed in off-cycle emissions.

C. Additional work: Adjust tech group-specific emissions to account for tech group to tech group variations in baseline VOC and toxics emissions as discussed in Appendix A.

IV. 1986-1994 Tier 0 cars, 1988-1994 Tier 0 trucks

A. Technology description: These vehicles are dominated by closed-loop technologies with adaptive learning. The mix of fuel distribution systems shifts away from carbureted and TBI systems to PFI systems. Both three-way and three-way plus oxidation catalyst designs are used.

B. Fuel effect quantification

The appropriate complex model technology types can be used. The relationship between vehicle technologies and Complex Model technology types is summarized below.

Technology	Complex Model Tech Types
Carbureted (3-way and 3-way+oxcat)	9
3-way PFI	Simple average of 1, 2, 5
3-way TBI	Simple average of 3 & 6
3-way+oxcat PFI	4
3-way+oxcat TBI	7
Higher emitters (all technologies)	Higher emitter

Off-cycle adjustments: T2AT uses a multiplicative adjustment factor to account for off-cycle adjustments for these and later vehicles. Toxics fractions will have to be modified to account for the different toxics fractions observed in off-cycle emissions.

C. Additional work: Adjust tech group-specific emissions to account for tech group to tech group variations in baseline VOC and toxics emissions, as described in Appendix A.

V. Tier 1 Vehicles

A. Technology description: These vehicles are dominated by closed-loop technologies, PFI fuel metering systems, and adaptive learning. Both three-way and three-way plus oxidation catalyst designs are used.

B. Fuel effect quantification: The appropriate complex model technology types can be used. The relationship between vehicle technologies and Complex Model technology types is summarized below.

Technology	**Complex Model Tech Types**
3-way PFI	Simple average of 1, 2, 5
3-way TBI	Simple average of 3 & 6
3-way+oxcat PFI	4
3-way+oxcat TBI	7
Higher emitters (all technologies)	Higher emitter

Off-cycle adjustments: T2AT uses a multiplicative adjustment factor to account for off-cycle adjustments for these and later vehicles. Toxics fractions will have to be modified to account for the different toxics fractions observed in off-cycle emissions.

C. Additional work: Adjust tech group-specific emissions to account for tech group to tech group variations in baseline VOC and toxics emissions, as per Appendix A.

VI. LEVs

A. Technology description: These vehicles are dominated by closed-loop technologies, PFI fuel metering systems, adaptive learning, and advanced catalysts. Three-way or three-way plus oxidation catalyst designs may be used.

B. Fuel effect quantification

1. Advanced catalyst designs show greater sulfur sensitivity than the Complex Model suggests. The CRC sulfur study should be used to develop the sulfur effect. The appropriate complex model technology types can be used for the other fuel parameters to calculate percentage changes in baseline toxics levels, which in turn can be calculated based on the CRC sulfur study results.

2. A less desirable alternative would be to use Complex Model baseline toxics emissions, adjusted to reflect lower VOC emissions from LEVs so that average normal emitter emissions for LEVs do not fall below the Complex Model normal level. The relationship between vehicle technologies and Complex Model technology types that could be used is summarized below.

Technology	Complex Model Tech Types
3-way PFI	Simple average of 1, 2, 5
3-way+oxcat PFI	4
Higher emitters (all technologies)	Higher emitter

It may be possible to further restrict the technology types used to evaluate the impact of fuel changes on LEVs if information becomes available that suggests EGR or supplementary air injection will become dominant.

3. Off-cycle adjustments: T2AT uses a multiplicative adjustment factor to account for off-cycle adjustments for these vehicles. Toxics fractions will have to be modified to account for the different toxics fractions observed in off-cycle emissions.

C. Additional work

1. Option 1: Calculate baseline toxics using CRC data.

2. Option 2: Adjust Complex Model baseline emissions to account for tech group to tech group variations in VOC and toxics emissions.

Appendix A: Adjusting Tech Group-Specific Emissions to Account for Tech Group to Tech Group Variations in VOC and Toxics

1. The complex model normal emitter baseline numbers for VOC (482 mg/mi in summer and 712 mg/mi in winter) and toxics are incorrectly assumed to be the same for all tech groups. They need to be corrected by multiplying normal emitter baseline VOC and toxics numbers by the following factors to reflect tech group to tech group variations in VOC emissions:

Tech	Correction	New Summer baseline fuel emissions (mg/mi)				
Group	Factor	VOC	BZ	Form	Acet	Buta
1	1.0223	493	27.298	5.913	2.424	2.671
2	0.8384	404	22.388	4.849	1.988	2.190
3	0.8458	408	22.585	4.892	2.006	2.210
4	1.5996	771	42.715	9.252	3.793	4.179
5	0.6582	317	17.577	3/807	1.561	1.720
6	0.7355	354	19.639	4.254	1.744	1.921
7	1.4305	689	38.198	8.274	3.392	3.737
9	0.9487	457	25.334	5.488	2.250	2.479

Winter VOC and toxics emissions would be 47.7% higher.

These emission factors should not be used to calculate in-use VOC or toxics emissions. Rather, these factors should be used to determine the percent change in VOC and toxics emissions due to fuel changes, which in turn should be applied to the VOC inputs to T2ATTOX and to the toxics outputs from T2ATTOX.

2. The complex model database suggests that toxics fractions are not the same across tech groups. However, no further correction will be made because the mix of test fuels differs across tech groups, thereby limiting the usefulness of the complex model database in correcting for tech group differences on baseline fuels. Furthermore, these differences are smaller than they first appear due to averaging.

3. The complex model's percent change values for fuel changes are correct.

Appendix E

Model-Year-Specific Technology Fractions

			Open-Loop		Closed-Loop					
IV	MYA	MYB	NCAT	CAT	Carb	3W PFI	3W TBI	3W+OX PF	3W+OX TBI	
1	65	74	100.00	0.00	0.00	0.00	0.00	0.00	0.00	100
1	75	75	20.00	80.00	0.00	0.00	0.00	0.00	0.00	100
1	76	77	15.00	85.00	0.00	0.00	0.00	0.00	0.00	100
1	78	79	10.00	90.00	0.00	0.00	0.00	0.00	0.00	100
1	80	80	5.00	95.00	0.00	0.00	0.00	0.00	0.00	100
1	81	81	0.00	28.10	62.90	6.00	0.00	0.10	2.90	100
1	82	82	0.00	32.50	50.60	6.20	6.70	0.00	4.00	100
1	83	83	0.00	24.40	48.60	8.50	11.50	0.20	6.80	100
1	84	84	0.00	5.80	55.00	10.50	15.90	0.50	12.30	100
1	85	85	0.00	7.60	40.80	29.20	5.80	1.60	15.00	100
1	86	86	0.00	2.40	31.90	32.90	13.30	6.40	13.10	100
1	87	87	0.00	1.70	24.90	34.70	21.70	2.40	14.60	100
1	88	88	0.00	0.00	10.10	44.40	32.70	4.80	8.00	100
1	89	89	0.00	0.30	12.50	54.60	23.90	5.10	3.60	100
1	90	90	0.00	0.10	1.80	71.80	19.40	4.30	2.60	100
1	91	91	0.00	0.00	0.30	77.50	18.90	2.10	1.20	100
1	92	92	0.00	0.29	0.00	86.47	9.56	3.68	0.00	100
1	93	93	0.00	0.00	0.00	89.06	10.94	0.00	0.00	100
1	94	94	0.00	0.00	0.00	96.12	3.88	0.00	0.00	100
1	95	95	0.00	0.00	0.00	98.80	1.20	0.00	0.00	100
1	96	99	0.00	0.00	0.00	100.00	0.00	0.00	0.00	100
1	00	00	0.00	0.00	0.00	100.00	0.00	0.00	0.00	100
1	01	03	0.00	0.00	0.00	100.00	0.00	0.00	0.00	100
1	04	50	0.00	0.00	0.00	100.00	0.00	0.00	0.00	100
2	65	74	100.00	0.00	0.00	0.00	0.00	0.00	0.00	100
2	75	75	30.00	70.00	0.00	0.00	0.00	0.00	0.00	100
2	76	76	20.00	80.00	0.00	0.00	0.00	0.00	0.00	100
2	77	78	25.00	75.00	0.00	0.00	0.00	0.00	0.00	100
2	79	80	20.00	80.00	0.00	0.00	0.00	0.00	0.00	100
2	81	81	3.00	95.20	1.80	0.00	0.00	0.00	0.00	100
2	82	82	0.00	96.10	3.90	0.00	0.00	0.00	0.00	100
2	83	83	2.60	84.10	13.10	0.20	0.00	0.00	0.00	100
2	84	84	0.00	72.80	25.00	2.20	0.00	0.00	0.00	100
2	85	85	0.00	62.90	25.80	6.60	4.70	0.00	0.00	100
2	86	86	0.00	49.50	13.10	23.80	9.10	0.00	4.50	100
2	87	87	0.00	26.40	12.80	20.40	22.30	12.30	5.80	100
2	88	88	0.00	5.00	9.20	28.00	37.00	13.60	7.20	100
2	89	89	0.00	1.40	7.70	33.10	30.70	20.90	6.20	100
2	90	90	0.10	1.20	2.00	41.20	32.50	18.70	4.30	100
2	91	91	0.00	0.10	1.50	43.50	36.20	14.20	4.50	100
2	92	92	0.48	0.87	0.76	54.15	31.82	11.86	0.06	100
2	93	93	0.00	0.00	1.10	58.00	30.08	10.82	0.00	100
2	94	94	0.00	0.00	0.00	62.13	27.21	10.66	0.00	100
2	95	95	0.00	0.00	0.00	63.92	25.36	10.72	0.00	100
2	96	96	0.00	0.00	0.00	63.00	25.00	12.00	0.00	100
2	97	97	0.00	0.00	0.00	69.08	20.00	10.92	0.00	100
2	98	98	0.00	0.00	0.00	75.16	15.00	9.84	0.00	100
2	99	99	0.00	0.00	0.00	81.24	10.00	8.76	0.00	100
2	00	00	0.00	0.00	0.00	87.32	5.00	7.68	0.00	100
2	01	03	0.00	0.00	0.00	93.40	0.00	6.60	0.00	100
2	04	50	0.00	0.00	0.00	93.40	0.00	6.60	0.00	100
3	65	78	100.00	0.00	0.00	0.00	0.00	0.00	0.00	100
3	79	80	0.00	100.00	0.00	0.00	0.00	0.00	0.00	100
3	81	81	3.00	95.20	1.80	0.00	0.00	0.00	0.00	100
3	82	82	0.00	96.10	3.90	0.00	0.00	0.00	0.00	100
3	83	83	2.60	84.10	13.10	0.20	0.00	0.00	0.00	100
3	84	84	0.00	72.80	25.00	2.20	0.00	0.00	0.00	100
3	85	85	0.00	62.90	25.80	6.60	4.70	0.00	0.00	100

3	86	86	0.00	49.50	13.10	23.80	9.10	0.00	4.50	100
3	87	87	0.00	26.40	12.80	20.40	22.30	12.30	5.80	100
3	88	88	0.00	5.00	9.20	28.00	37.00	13.60	7.20	100
3	89	89	0.00	1.40	7.70	33.10	30.70	20.90	6.20	100
3	90	90	0.10	1.20	2.00	41.20	32.50	18.70	4.30	100
3	91	91	0.00	0.10	1.50	43.50	36.20	14.20	4.50	100
3	92	92	0.48	0.87	0.76	54.15	31.82	11.86	0.06	100
3	93	93	0.00	0.00	1.10	58.00	30.08	10.82	0.00	100
3	94	94	0.00	0.00	0.00	62.13	27.21	10.66	0.00	100
3	95	95	0.00	0.00	0.00	63.92	25.36	10.72	0.00	100
3	96	96	0.00	0.00	0.00	63.00	25.00	12.00	0.00	100
3	97	97	0.00	0.00	0.00	69.08	20.00	10.92	0.00	100
3	98	98	0.00	0.00	0.00	75.16	15.00	9.84	0.00	100
3	99	99	0.00	0.00	0.00	81.24	10.00	8.76	0.00	100
3	00	00	0.00	0.00	0.00	87.32	5.00	7.68	0.00	100
3	01	03	0.00	0.00	0.00	93.40	0.00	6.60	0.00	100
3	04	50	0.00	0.00	0.00	93.40	0.00	6.60	0.00	100
4	68	81	100.00	0.00	0.00	0.00	0.00	0.00	0.00	100
4	82	86	95.00	5.00	0.00	0.00	0.00	0.00	0.00	100
4	87	87	70.00	30.00	0.00	0.00	0.00	0.00	0.00	100
4	88	89	60.00	40.00	0.00	0.00	0.00	0.00	0.00	100
4	90	95	7.00	93.00	0.00	0.00	0.00	0.00	0.00	100
4	96	99	5.00	95.00	0.00	0.00	0.00	0.00	0.00	100
4	00	00	2.00	98.00	0.00	0.00	0.00	0.00	0.00	100
4	01	04	2.00	98.00	0.00	0.00	0.00	0.00	0.00	100
4	05	20	0.00	100.00	0.00	0.00	0.00	0.00	0.00	100
5	65	50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	65	50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	65	50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	65	20	100.00	0.00	0.00	0.00	0.00	0.00	0.00	100

Appendix F

Evaluation of CARB UC-FTP Database

The Off–Cycle Toxics Adjustment Factor Analysis

Background: Work Assignment 0-07 involves the estimation of on-road motor vehicle air toxic emissions, exposure, and cancer risk. The basic on-road emissions analysis requires an assessment of both on- and off-cycle emissions performance. As a key component of their Tier 2 emission standards study, the U.S. Environmental Protection Agency (EPA) has previously developed an approach for estimating off-cycle impacts on the criteria pollutants HC, CO, and NO_x.[1] Since that approach is carried over to the HC (as TOG) and CO components of Work Assignment 0-07, a similar approach to the consideration of off-cycle impacts on toxic emissions (which were not considered in the previous Tier 2 study) is required.

The EPA approach essentially involves the assumption that emissions measured over the Unified Cycle (UC) accurately reflect the aggressive driving aspects of actual on-road performance and, therefore, the relationship of UC measured emissions to Federal Test Procedure (FTP) measured emissions provides the necessary adjustment factors to account for off-cycle (aggressive driving) emission impacts. This appendix details the approach undertaken to derive the UC/FTP relationship for five toxic species: benzene, 1,3-butadiene, MTBE, formaldehyde, and acetaldehyde. The ultimate form of the derived relationships is expressed as, as described in Section 4 of the main report, the ratio of the UC toxics fraction of TOG to the FTP toxics fraction of TOG.

The EPA approach also involves the application of an additional set of adjustment factors to account for on-road air conditioning usage not reflected in either the standard FTP or UC. However, for HC (as TOG), the air conditioning adjustments are minor relative to the UC off-cycle aggressive driving adjustments. Whereas the aggressive driving TOG adjustments can be as high as 30 percent for some vehicle model years, air conditioning corrections are confined to a range of -2 percent to +4 percent. In the absence of specific speciated test data on which to base toxic air conditioning adjustment factors and because air conditioning represents a relatively constant load (when activated), it was assumed that on-cycle (i.e., FTP) toxic fractions are accurate over both on- and off-cycle air conditioning operation. Given the order-of-magnitude difference in aggressive driving and air conditioning impacts on TOG emission rates, any error associated with this assumption will be small.

Aggressive Driving Approach: A small database of toxic emissions measurements collected over the REP05, US06, and FTP cycles was provided by EPA staff for use in determining off-cycle aggressive driving toxics adjustment factors. Unfortunately, a basic review of the database revealed several areas of concern limiting its utility. Table A-1 provides an overview of the database and illustrates most of the limiting factors. First, all vehicles with reported

[1] "Tier 2 Study", Draft Report, EPA420-P-98-009, U.S. Environmental Protection Agency, April 23, 1998.

Table A-1
Description of REP05/US06 Database

Vehicles Tested

Model Year	Model	Type	Test Fuel(s)
1995	Caravan	Gasoline LDT	2% MTBE
1993	Taurus	M-FFV	2% MTBE
1993	Spirit	M-FFV	2% MTBE
1993	Lumina	E-FFV	2% MTBE
1994	Dodge B250	Gasoline LDT	not reported
1995	Intrepid	Gasoline LDV	not reported
1995	Taurus	Gasoline LDV	not reported
1989	Camry	Gasoline LDV	Non-Oxy and 2% MTBE
1989	Grand Am	Gasoline LDV	Non-Oxy and 2% MTBE
1989	Taurus	Gasoline LDV	Non-Oxy and 2% MTBE
1989	Sundance	Gasoline LDV	Non-Oxy and 2% MTBE
not reported	Chevrolet C-20 Pickup	CNG	CNG
not reported	Crown Victoria	CNG	CNG
not reported	Dodge B150 Ram Wagon	CNG	CNG

Speciated Emissions Test Data Points

Species	REP05/FTP	US06/FTP	REP05/US06	Comments
Formaldehyde	18	3	0	a
Acetaldehyde	18	3	0	a
1,3-Butadiene	17	0	0	a
Benzene	18	0	0	a
MTBE	7	0	0	b
TOG	4	3	0	

Comments: a. REP05/FTP data points comprise 11 vehicles in total, 7 of which were tested on multiple fuels. 3 of 11 REP05/FTP vehicles and 6 of 18 data points are associated with CNG vehicle testing.

b. 3 of 7 REP05/FTP vehicles and data points are associated with CNG vehicle testing.

model years fall within the very narrow range of 1989-1995. Second, three of the eleven vehicles tested are CNG powered and, therefore, not reflective of typical on-road fleet impacts. Third, there is no mechanism inherent in the database to adjust for differences in the REP05 and US06 cycles (i.e., no vehicles were tested over both cycles). Fourth, only a fraction of the data includes simultaneous toxics species and TOG measurements. Finally, neither the REP05 or US06 test cycles are reflective of emissions performance over the UC used for TOG off-cycle adjustment factor development. Both REP05 and US06 incorporate much higher fractions of off-cycle driving than the UC (and, theoretically, on-road operation which the UC was designed to reflect). Therefore, while off-cycle to on-cycle toxics ratios can be developed from the data, a secondary method of determining the fraction of on-road operation accumulated in each mode would be required (as well as a method to equilibrate the two varying test cycles (i.e., the REP05 and the US06) in the EPA database.

Based on the deficiencies noted, supplemental sources of off-cycle toxics data were investigated and it was determined that the California Air Resources Board (CARB) had performed a substantial number of speciated emissions tests over both the UC and FTP cycles. Since such data alleviates several (but not all, as discussed below) of the deficiencies of the REP05/US06 database, the CARB UC/FTP database was obtained and utilized as the basis for the off-cycle (aggressive driving) adjustment factors used in the performance of this work assignment.

The CARB FTP/UC Database: CARB provided results from 36 speciated emissions tests, 18 of which were performed over the FTP cycle and 18 of which were performed over the UC. A total of 13 different test vehicles are represented. In all but one case, each of the 18 FTP tests can be matched with a corresponding UC test, where both tests are conducted on the same vehicle, using the same fuel, with only moderate mileage accumulation (in many cases, only the mileage associated with the first test cycle) between tests. However, for a single test pair, the fuel reported for the FTP test does not match the fuel reported for the UC test. Given the influence test fuel can play on measured emissions, this single mismatched test pair was excluded from all analysis under this work assignment. Table A-2 presents an overview of the CARB test data.

As indicated in Table A-2, of the 12 “matching fuel” vehicles in the database, 9 were tested once over both the FTP and the UC while operating on one of two fuels, either commercial unleaded gasoline (2 vehicles) or California Phase 2 Reformulated Gasoline (7 vehicles). Two of the remaining three matching fuel vehicles were tested twice over the FTP and twice over the UC, once while operating on indolene and once while operating on commercial unleaded gasoline. One matching fuel vehicle was tested four times over the FTP and four times over the UC, once each on California Phase 2 Reformulated Gasoline and indolene and twice on commercial unleaded gasoline. The “mismatched fuel” vehicle (see arbitrarily labeled tests 18A and 18B in Table A-2), which was excluded from all toxics adjustment factor analysis, was reported to have been tested on commercial unleaded gasoline over the FTP and California Phase 2 Reformulated Gasoline over the UC. Unfortunately CARB was unable to provide fuel specification data for any of the test fuels so the specific variation in fuel properties is not available. However, test dates indicate that some of the commercial unleaded gasoline testing was performed prior to the requirement that all California gasoline meet Phase 2 Reformulated Gasoline specifications.

Table A-2
Synopsis of the CARB FTP/UC Database

Test Number	Model Year	Vehicle Make	Vehicle Model	Engine Family	Odometer Reading	Test Type	Test Fuel	High Emitter?	THC (g/mi)	TOG (g/mi)	Benzene (mg/mi)	1,3-Butad (mg/mi)	MTBE (mg/mi)	Formald (mg/mi)	Acetald (mg/mi)
1A	1996	FORD	TAURUS GL	TFM3.0V8GKEK	43077	FTP	RFG	No	0.1257	0.1311	3.8733	0.4719	4.0072	1.5937	0.5032
1B					43088	UC			0.1309	0.1377	3.4630	0.2598	3.4306	3.9426	0.4645
2A	1995	TOTA	COROLLA DX	STY1.8VJG1GA	12302	FTP	UnL	No	0.1606	0.1662	4.6247	0.8189	3.6832	2.6499	0.5278
2B					12313	UC			0.1301	0.1345	4.8528	1.0670	2.3777	1.8564	0.4098
3A	1994	GM	SUNBIRD LE4DR	R1G2.0V7GFEA	53752	FTP	RFG	No	0.1924	0.2045	4.6924	0.9455	6.5115	4.4394	1.0985
3B					53774	UC			0.1344	0.1429	4.1695	0.6358	3.6821	4.0374	0.6821
4A	1993	FORD	TAURUS GL	PFM3.8V5FAC8	7429	FTP	Ind	No	0.0501	0.0536	1.7666	0.1902	0.1345	2.6240	0.2053
4B					7964	UC			0.1164	0.1244	5.8468	0.3080	0.0000	6.3267	0.5020
5A	1993	FORD	TAURUS GL	PFM3.8V5FAC8	7834	FTP	UnL	No	0.1223	0.1272	6.2116	0.7034	3.1396	2.9638	0.4069
5B					7798	UC			0.1239	0.1260	9.7737	0.4274	2.6549	0.4605	0.4898
6A	1993	FORD	TAURUS GL	PFM3.8V5FAC8	8010	FTP	UnL	No	0.0913	0.0923	3.9428	0.4036	3.1161	0.6365	0.1414
6B					7850	UC			0.1181	0.1209	9.3815	0.7331	2.1953	0.9556	0.5244
7A	1993	FORD	TAURUS GL	PFM3.8V5FAC8	7890	FTP	RFG	No	0.0886	0.0920	3.1039	0.4695	2.7508	2.0666	0.3862
7B					7901	UC			0.1005	0.1117	5.4411	0.2481	2.9428	9.6098	0.4014
8A	1992	CHRY	WRANGLER 2DR	NCR242T5FEFX	65196	FTP	RFG	No	0.2833	0.2941	8.2053	1.3462	10.8351	4.0166	1.2080
8B					65255	UC			0.3644	0.3763	9.0569	1.1907	17.9644	4.4172	1.0991
9A	1989	FORD	TRACER	KFM1.6V5FC9	104715	FTP	Ind	No	0.1847	0.1888	6.0074	0.8885	0.0000	2.4745	0.4316
9B					104497	UC			0.1844	0.1872	6.9607	0.9538	0.0000	0.8445	0.5624
10A	1989	FORD	TRACER	KFM1.6V5FC9	104661	FTP	UnL	No	0.2324	0.2531	6.3636	0.6818	4.7496	10.9043	0.7099
10B					104613	UC			0.2730	0.2870	9.1525	0.9992	2.4148	10.4562	0.9512
11A	1989	TOTA	CAMRY	KTY2.0V5FCC1	129092	FTP	UnL	No	0.2274	0.2318	7.9994	1.2267	0.0000	2.0930	0.7367
11B					129115	UC			0.3742	0.3835	21.8217	2.8594	0.0000	2.8130	1.7792
12A	1987	MAZD	626LXi 2DR	HTK2.0V5FAK3	223589	FTP	RFG	Yes	1.7677	1.8764	72.7795	17.5925	24.4603	42.0528	11.3426
12B					223628	UC			1.7501	1.8629	76.8858	15.4418	16.0411	43.7857	12.1923
13A	1984	FORD	P/U F-250	EFM4.9T1HGG5	36660	FTP	RFG	No	0.3766	0.3841	12.1466	0.7973	11.5648	3.6149	0.9507
13B					36671	UC			0.4903	0.4985	24.0186	1.0149	9.2366	3.6696	1.1920
14A	1984	MITS	COLT	EMT1.6V2FCA5	122337	FTP	RFG	Yes	1.4099	1.5309	35.7490	14.6033	70.4496	51.3210	11.6262
14B					122337	UC			1.6163	1.7264	42.4803	8.0979	80.0602	43.8942	10.2241
15A	1983	CHRY	VAN RAM150	DCR3.7T1AHS4	114222	FTP	RFG	Yes	2.2895	2.3704	59.8553	4.4287	21.4863	25.0328	7.7771
15B					114247	UC			2.3424	2.4041	82.2424	3.1607	12.3718	25.0180	7.6806
16A	1982	GM	CORVETTE	C1G5.7V5NBM2	131965	FTP	Ind	Yes	1.7809	1.8317	69.9380	5.3410	0.0000	21.8404	8.8994
16B					131974	UC			1.5220	1.5728	67.7398	3.9056	1.2878	24.6744	6.5080
17A	1982	GM	CORVETTE	C1G5.7V5NBM2	132030	FTP	UnL	Yes	1.4140	1.4803	58.0894	6.0390	13.5599	23.5275	7.8022
17B					131910	UC			1.4043	1.4656	59.3127	4.7875	20.4828	12.9383	7.2346
18A	1991	FORD	TAURUS	MFM3.0V5FX03	69189	FTP	UnL	No	0.4205	0.4328	13.2492	1.4970	8.5297	3.4716	1.2526
18B					69134	UC	RFG		0.3703	0.3828	10.7827	0.8301	8.0156	3.4596	1.1353

Fuel type "RFG" indicates California Phase 2 Reformulated Gasoline, "Ind" indicates indolene, and "UnL" indicates commercial unleaded gasoline.

"1,3-Butad" indicates 1,3-butadiene, "Formald" indicates formaldehyde, and "Acetald" indicates "acetaldehyde."

As mentioned above, most of the corresponding FTP and UC tests were performed with only moderate mileage accumulation between tests. Of the 10 vehicles tested once (including the mismatched fuel vehicle), the maximum reported mileage between FTP and UC test initiation is believed to be 59 miles (the uncertainty derives from the fact that identical FTP and UC start mileages are reported for one test vehicle). In all single test matched fuel cases, the FTP was performed first. For vehicles tested multiple times on different fuels, greater mileage accumulation is evident between tests on differing fuels to ensure that any emissions effects associated with the preceding test fuel do not affect the following test performance. Additionally, multiple fuel testing was not always performed sequentially (i.e., same-fuel FTP and UC tests were not always performed consecutively), so that accumulations of one to two hundred miles are observed between several corresponding multi-fuel tests, with a single test pair separated by a maximum of 535 miles (due to the performance of 5 tests on other fuels between the matching test pair).

The CARB database was subjected to a basic integrity check prior to off-cycle adjustment factor analysis. This check detected two potential problem areas. First, test pair 4A/4B (see Table A-2) was determined to be invalid. As evidenced by the emission measurements presented in Table A-2, the FTP/UC relationship for this test pair is an outlier. Further review of the CARB test data indicates that the CO_2 emission rate over the FTP (test 4A) is reported to be only 168 grams per mile, while that over the UC (test 4B) is a much more reasonable 439 grams per mile. Clearly there is a quality problem with this test pair that appears to be traceable to a test 4A dilution factor calculation error (given the apparent under-reporting of all test species). Since sufficient information to confirm or correct such an error is not included in the data provided by CARB, the test 4A/4B pair was dropped from the analysis database. The UC CO_2/FTP CO_2 relationship for all other test pairs varies from -2 percent to +13 percent (with both matching fuel test pairs indicating a negative relationship being high emitters), so that no other obvious data quality problems are apparent.

The second data integrity problem area was an apparent discrepancy in the treatment of THC, CH_4, and NMHC emission rates on all tests. Essentially, CARB appears to correct THC measurements for FID CH_4 “over-response,” but does not apply this same correction to CH_4 itself. Since NMHC is then determined as THC minus CH_4, the reported CH_4 emission rate appears to be somewhat high (on the order of 5 percent or so depending on FID CH_4 response) and the reported NMHC emission rate appears to be correspondingly low. However, unlike the previous under-measurement problem with test 4A, this problem is easily resolved. Since TOG emissions are the basis for all off-cycle toxics fractions, only the THC (plus alcohol and carbonyl) measurement need be precise. Moreover, all information necessary to correct both the reported CH_4 and NMHC measurements is available in the data provided by CARB. Therefore, this potential problem area does not ultimately affect the off-cycle toxics analysis (but care was taken to ensure that all data used in the analysis was consistent).

Determination of Off-Cycle Toxic Adjustment Factors: As described above (and as shown in Table A-2), a total of 16 matched fuel UC/FTP speciated test pairs were available to support a determination of the required off-cycle toxics adjustment factors (test pairs 4A/4B and 18A/18B were excluded due to data integrity and fuel mismatch problems respectively). Ideally, off-cycle adjustment factor analysis would be conducted on a vehicle technology, vehicle class, and fuel specific basis to ensure that all vehicle- and fuel-specific influences were properly accounted for in the calculated adjustment factors. However, the size of the available database precludes such disaggregated treatment. Nevertheless, several precautions were taken to minimize any unaccounted for vehicle- and fuel-specific influences. First, all off-cycle adjustments are calculated in normalized form as the ratio of the UC toxic fraction to the FTP toxics fraction. Therefore, both vehicle- and fuel-specific influences will be controlled to the extent that such influences are consistent across the FTP and UC. Second, in determining MTBE ratios, all zero content MTBE fuels were excluded from analysis since exhaust MTBE emissions for such fuels will be at or near zero. Third, the CARB test data was collapsed so that each test vehicle is represented in the off-cycle adjustment database only once. Test results for vehicles that were tested multiple times were consolidated into a single UC/FTP test pair by arithmetically averaging individual test results. Finally, several statistical checks were applied to ensure no obvious problems with the aggregated treatment of the CARB data. Table A-3 presents the off-cycle toxics database after the application of the described quality control steps.

Following exclusion of suspect quality data, aggregation of multiple test vehicle results, and elimination of the zero MTBE content fuel results for MTBE adjustment factor analysis, the analysis database consists of:

- 8 normal emitter test pairs for benzene, 1,3-butadiene, formaldehyde, and acetaldehyde analysis,
- 7 normal emitter test pairs for MTBE analysis, and
- 4 high emitter test pairs for benzene, 1,3-butadiene, MTBE, formaldehyde, and acetaldehyde analysis.

Due to the small sample sizes available for adjustment factor development, an aggregated approach based on the development of single adjustment factors for normal and high emitters was employed. Such an approach allows for the development of model year specific adjustment factors through the appropriate weighting of the normal and high emitter adjustments (as described in Section 4), but explicitly discounts any inherent influences of vehicle technology, class, or fuel. Given the limitations imposed by database size, it is difficult to be certain that such overlooked influences are not significant, but basic analyses possible with the given data imply that they are no more significant than seemingly random variations in the dataset. To some extent, this is expected given the normalization approach employed in this analysis. While technology and fuel may influence emissions, much of that influence should be consistent across both the FTP and UC cycles and, therefore, "factored out" during the normalization process. This does not imply any loss in fuel or technology significance in the overall toxics exposure analysis, since the basic differences due to fuels and technology will be reflected in the basic emission rates to which the off-cycle adjustments are applied.

Table A-3
FTP/UC Database used for Off-Cycle Adjustment Analysis

Test Number	Model Year	Vehicle Make	Vehicle Model	Engine Family	Odometer Reading	Test Type	Test Fuel	High Emitter?	THC (g/mi)	TOG (g/mi)	Benzene (mg/mi)	1,3-Butad (mg/mi)	MTBE (mg/mi)	Formald (mg/mi)	Acetald (mg/mi)
1A	1996	FORD	TAURUS GL	TFM3.0V8GKEK	43077	FTP	RFG	No	0.1257	0.1311	3.8733	0.4719	4.0072	1.5937	0.5032
1B					43088	UC			0.1309	0.1377	3.4630	0.2598	3.4306	3.9426	0.4645
2A	1995	TOTA	COROLLA DX	STY1.8VJG1GA	12302	FTP	UnL	No	0.1606	0.1662	4.6247	0.8189	3.6832	2.6499	0.5278
2B					12313	UC			0.1301	0.1345	4.8528	1.0670	2.3777	1.8564	0.4098
3A	1994	GM	SUNBIRD LE4DR	R1G2.0V7GFEA	53752	FTP	RFG	No	0.1924	0.2045	4.6924	0.9455	6.5115	4.4394	1.0985
3B					53774	UC			0.1344	0.1429	4.1695	0.6358	3.6821	4.0374	0.6821
5-7A	1993	FORD	TAURUS GL	PFM3.8V5FAC8	7911	FTP	UnL/RFG	No	0.1007	0.1038	4.4194	0.5255	3.0021	1.8889	0.3115
5-7B					7850	UC			0.1142	0.1196	8.1988	0.4695	2.5976	3.6753	0.4719
8A	1992	CHRY	WRANGLER 2DR	NCR242T5FEFX	65196	FTP	RFG	No	0.2833	0.2941	8.2053	1.3462	10.8351	4.0166	1.2080
8B					65255	UC			0.3644	0.3763	9.0569	1.1907	17.9644	4.4172	1.0991
9-10A	1989	FORD	TRACER	KFM1.6V5FC9	104688	FTP	Ind/UnL	No	0.2085	0.2210	6.1855	0.7851		6.6684	0.5708
9-10B					104555	UC			0.2287	0.2371	8.0566	0.9765		5.6504	0.7568
10A	1989	FORD	TRACER	KFM1.6V5FC9	104661	FTP	UnL	No	0.2324	0.2531			4.7496		
10B					104613	UC			0.2730	0.2870			2.4148		
11A	1989	TOTA	CAMRY	KTY2.0V5FCC1	129092	FTP	UnL	No	0.2274	0.2318	7.9994	1.2267		2.0930	0.7367
11B					129115	UC			0.3742	0.3835	21.8217	2.8594		2.8130	1.7792
13A	1984	FORD	P/U F-250	EFM4.9T1HGG5	36660	FTP	RFG	No	0.3766	0.3841	12.1466	0.7973	11.5648	3.6149	0.9507
13B					36671	UC			0.4903	0.4985	24.0186	1.0149	9.2366	3.6696	1.1920
12A	1987	MAZD	626LXi 2DR	HTK2.0V5FAK3	223589	FTP	RFG	Yes	1.7677	1.8764	72.7795	17.5925	24.4603	42.0528	11.3426
12B					223628	UC			1.7501	1.8629	76.8858	15.4418	16.0411	43.7857	12.1923
14A	1984	MITS	COLT	EMT1.6V2FCA5	122337	FTP	RFG	Yes	1.4099	1.5309	35.7490	14.6033	70.4496	51.3210	11.6262
14B					122337	UC			1.6163	1.7264	42.4803	8.0979	80.0602	43.8942	10.2241
15A	1983	CHRY	VAN RAM150	DCR3.7T1AHS4	114222	FTP	RFG	Yes	2.2895	2.3704	59.8553	4.4287	21.4863	25.0328	7.7771
15B					114247	UC			2.3424	2.4041	82.2424	3.1607	12.3718	25.0180	7.6806
16-17A	1982	GM	CORVETTE	C1G5.7V5NBM2	131998	FTP	Ind/UnL	Yes	1.5974	1.6560	64.0137	5.6900		22.6840	8.3508
16-17B					131942	UC			1.4631	1.5192	63.5262	4.3466		18.8063	6.8713
17A	1982	GM	CORVETTE	C1G5.7V5NBM2	132030	FTP	UnL	Yes	1.4140	1.4803			13.5599		
17B					131910	UC			1.4043	1.4656			20.4828		

Fuel type "RFG" indicates California Phase 2 Reformulated Gasoline, "Ind" indicates indolene, and "UnL" indicates commercial unleaded gasoline.
"1,3-Butad" indicates 1,3-butadiene, "Formald" indicates formaldehyde, and "Acetald" indicates "acetaldehyde."
Test pairs 9-10A/9-10B, 11A/11B, and 16-17A/16-17B are excluded from MTBE adjustment factor development due to zero MTBE content fuel use.
Test pairs 10A/10B and 17A/17B are used only for MTBE adjustment factor development (both pairs exclude zero MTBE content fuel test results).
For multiple test pairs, the tabulated odometer readings are the arithmetic average of component test readings.

Some degree of assessment of the potential significance of fuel effects can be attained by examining the CARB data for the three vehicles that were tested multiple times on different fuels. CARB tested a 1993 Ford Taurus once on indolene, once on California Phase 2 Reformulated Gasoline, and twice on commercial unleaded gasoline. Comparing the variation in the ratio of the UC toxics fraction (of TOG) to the FTP toxics fraction (of TOG) when tested on the two commercial unleaded gasolines to the overall variation indicates that the unleaded variation comprises 58 percent of the overall variation for benzene, 81 percent of the overall variation for 1,3-butadiene, 92 percent of the overall variation for MTBE, 27 percent of the overall variation for formaldehyde, and 82 percent of the overall variation for acetaldehyde. With the exception of formaldehyde, almost as much variability is observed between results for the two commercial unleaded fuels as is observed over the entire four tests. While formaldehyde appears to be an exception, nearly all the difference can be tied to a single UC test result that is not supported by a similar difference in FTP results. Therefore, the source of the variation does not appear to be fuel related.

CARB also tested two other vehicles on two fuels each. A 1989 Ford Tracer tested on both indolene and commercial unleaded gasoline indicated total toxics fraction ratio variability across the two fuels of only 9 percent for benzene, 19 percent for 1,3-butadiene, and 10 percent for acetaldehyde. Once again, formaldehyde indicates significant variability, with a 146 percent difference. Data for MTBE is only available for one fuel. A 1982 Chevrolet Corvette also tested on both indolene and commercial unleaded gasoline indicates similar variabilities across fuels of only 9 percent for benzene, 6 percent for 1,3-butadiene, and 10 percent for acetaldehyde. Formaldehyde variability is again significant, but interestingly the variability is opposite in sign to that for the Tracer and of virtually identical magnitude (-58 percent versus +146 percent difference). As a result, it is not possible to identify any definitive fuel-specific influences within the small sample available for analysis. Additional inferences may have been possible had specific fuel specifications been available, but CARB did not respond to a request for such data. Nevertheless, it does appear that fuel effects are not the predominant influence for a normalization-based approach such as that employed in this analysis and the uncertainty associated with treating all fuels in the aggregate is expected to be only a small component of overall analysis uncertainty.

To assess the potential impacts of vehicle technology, a basic regression of the ratio of UC toxics fraction (of TOG) to FTP toxics fraction (of TOG) by vehicle model year was conducted. The results of this regression analysis are presented in the upper half of Table A-4. Notwithstanding the very small sample sizes, not a single model year coefficient or intercept is significant at over 90 percent confidence. A case for a formaldehyde relationship can be made over the entire 8 normal emitter vehicle dataset as both coefficient and intercept are significant at 90 percent confidence, but further examination indicates that this relationship is controlled by a single data point for a 1996 Ford Taurus. When excluded, the confidence level of both the coefficient and the intercept decline to just over 75 percent and “random” effects appear to dominate the model year relationship. Based on this, albeit simplistic, analysis, it does not appear that vehicle technology influences are a predominant factor, at least in the database available for this analysis. One additional observation is, however, critical. The database available for analysis does not include any pre-1981 model year vehicles. Therefore, potential

Table A-4
Database Regression Analysis Results

Emitter Category	Toxics Species	Number of Data Points	r^2	F	a	Confidence Level of a	b	Confidence Level of b	Zero Intercept Slope	Avg UC Fraction to Avg FTP Fraction	Slope/Avg Delta
UC/FTP Toxic Fraction Ratio = a (Vehicle Model Year) + b											
Normal Emitters	Benzene	8	0.239	1.887	-0.038	78%	77.181	79%			
	1,3-Butadiene	8	0.034	0.211	-0.017	34%	34.870	35%			
	MTBE	7	0.153	0.901	0.024	61%	-47.043	61%			
	Formaldehyde	8	0.393	3.882	0.091	90%	-179.436	90%			
	Acetaldehyde	8	0.090	0.590	-0.019	53%	39.523	54%			
High Emitters	Benzene	4	0.121	0.275	-0.023	35%	47.337	36%			
	1,3-Butadiene	4	0.062	0.133	0.020	25%	-39.418	25%			
	MTBE	4	0.352	1.086	-0.134	59%	267.275	59%			
	Formaldehyde	4	0.189	0.467	0.025	44%	-49.168	43%			
	Acetaldehyde	4	0.338	1.020	0.034	58%	-67.168	58%			
UC Toxics Fraction = a (FTP Toxics Fraction) + b											
Normal Emitters	Benzene	8	0.782	21.558	2.425	100%	-0.034	92%	1.350	1.315	-3%
	1,3-Butadiene	8	0.483	5.599	1.458	94%	-0.002	47%	1.060	1.037	-2%
	MTBE	7	0.758	15.628	1.893	99%	-0.031	92%	0.856	0.825	-4%
	Formaldehyde	8	0.336	3.032	0.811	87%	0.006	49%	1.113	1.163	5%
	Acetaldehyde	8	0.280	2.335	0.470	82%	0.002	87%	0.986	1.020	3%
High Emitters	Benzene	4	0.835	10.109	0.878	91%	0.008	53%	1.113	1.126	1%
	1,3-Butadiene	4	0.741	5.727	0.649	86%	0.000	13%	0.694	0.708	2%
	MTBE	4	0.943	33.381	1.018	97%	-0.001	16%	0.986	0.965	-2%
	Formaldehyde	4	0.879	14.547	0.695	94%	0.004	58%	0.861	0.894	4%
	Acetaldehyde	4	0.743	5.788	0.713	86%	0.001	43%	0.904	0.919	2%

influences associated with major catalyst technology differences cannot be ascertained. Too some extent, this problem is alleviated through the predominance of 1981 and later vehicles in the future year fleets addressed in the overall toxics exposure analysis. Nevertheless, a significant fraction of such vehicles are present in the 1990 analysis fleet. Therefore, given the complete absence of data for such vehicles, off-cycle adjustment factors have been set to unity for pre-1981 LDV's and pre-1984 LDT's as described in Section 4 of the main report.

Based on the negative assessments of fuel and model year influences, an aggregate treatment of the CARB test data appears to be justified. As outlined in Section 4 of the main report, the desired application of the off-cycle adjustment is multiplicative in design. However, before such application was accepted, a basic regression analysis of the CARB data was performed to ensure that no absolute offsets were present in the UC/FTP relations. The bottom half of Table A-4 presents the results of a regression analysis of the UC toxics fraction (of TOG) versus the FTP toxics fraction (of TOG). As indicated, significant intercepts were found in no cases at 95 percent confidence and only two cases at 90 percent confidence. Conversely, significant coefficients were found at 95 percent or greater confidence in 3 of 10 relations (including both of those where intercepts were significant at 90 percent confidence) and at 90 percent or greater confidence in 6 of 10 relations. All four remaining relations showed significant coefficients only between 80 and 90 percent confidence, but in all cases but one coefficient significance exceeded intercept significance (in most cases by substantial margins). While the calculated relations are not definitive in their confirmation of the superiority of a multiplicative approach in all cases, they strongly suggest that such an approach is as or more reliable than an approach which includes an emissions offset given available data.

The three rightmost columns of the bottom half of Table A-4 present results for two approaches to the determination of multiplicative off-cycle adjustment factors. One approach relies on zero intercept regression coefficients, while the second is simply the ratio of the arithmetic average of UC toxic fractions to the arithmetic average of FTP fractions. By definition, these two estimates must be similar and, as shown in Table 4, the observed variation is ±5 percent. Given this similarity and the fact that the regression statistics are based on very small datasets, the estimates derived through the arithmetic average approach were used for all subsequent toxics analysis. Table A-5 presents a final summary of the off-cycle adjustment factors and includes the minimum and maximum UC/FTP toxic fraction ratios for test data included in the arithmetic average statistics. With the exception of MTBE, the range of ratios tends to be much smaller for high emitters and, with the exception of 1,3-butadiene and acetaldehyde, closer to unity.

Clearly there is considerable uncertainty in the derived off-cycle adjustment factor estimates given the quantity of available data. This uncertainty extends to the issue of whether vehicle technology and fuel influences are, in fact, significant and just not identifiable given the relative scatter of data over such a small database. Moreover, normal emitter adjustment factors for both 1,3-butadiene and acetaldehyde are sufficiently close to unity such that the collection of additional data is required before even directional differences can be known with certainty. While additional data should be collected to support more finely detailed analysis in the future, the derived estimates appear reasonable, with the largest implied adjustment on the order of 30 percent.

Table A-5
Summary of Off-Cycle Toxics Adjustment Factor Analysis

Toxic Species	Parameter	Normal Emitters		High Emitters	
		Regression Coefficient	Arithmetic Average	Regression Coefficient	Arithmetic Average
Benzene	Ratio Estimate	1.350	1.315	1.113	1.126
	Minimum		0.851		1.054
	Maximum		1.649		1.355
	Data Points	8	8	4	4
1,3-Butadiene	Ratio Estimate	1.060	1.037	0.694	0.708
	Minimum		0.524		0.492
	Maximum		1.610		0.884
	Data Points	8	8	4	4
MTBE	Ratio Estimate	0.856	0.825	0.986	0.965
	Minimum		0.474		0.568
	Maximum		1.296		1.647
	Data Points	7	7	4	4
Formaldehyde	Ratio Estimate	1.113	1.163	0.861	0.894
	Minimum		0.782		0.758
	Maximum		2.354		1.049
	Data Points	8	8	4	4
Acetaldehyde	Ratio Estimate	0.986	1.020	0.904	0.919
	Minimum		0.711		0.780
	Maximum		1.460		1.083
	Data Points	8	8	4	4

Appendix G

Summary of T2ATTOX Code Changes to Implement Revised Toxics Emissions Estimation Procedures and Description of Model Function

X6	I	Added variables to store values for July Runs
BD38	FOR	Added initializations for X6 Common Block
BD41	FOR	Initializations for TOX variables
BEF	FOR	Added calls to TOXADJ and OFFCYC routines
CCEVRT	FOR	No Change
DAT01	I	Contains Common block for TOX changes
DRIVER	FOR	Modified to automate Output file name
EVPADJ	FOR	Modified to do multiple Toxics
GETTX2	FOR	Reads in Evap and Exhaust Tox factors and Offcycle factors; Sets up TOX and Offcycle arrays.
HCCALX	FOR	Modified to handle multiple Toxic calculations
IM90	OFF	Offcycle file used in Tox input file
LASTOUT	FOR	Writes out output header to the screen
NAMEOUT	FOR	Develops output file name
OFFCYC	FOR	Offcycle adjustments routine
ONESEC	FOR	Modified to run with only with NMHFLG=7 (File input)
OUTDT3	FOR	Outputs multiple Toxic EFs
OUTDT4	FOR	Outputs multiple toxic EFs
OUTTOX	FOR	Prints out Toxic/Off cycle factors used
PX90SB	EVP	Evap Toxic factor input file
PX96SB	EXH	Exhaust Toxic factor input file
SAVER	FOR	Saves output for Jul run
TOXADJ	FOR	Applies Toxic Emission corrections
VNAME	I	Header changes
ADJUST	FOR	Applies adjustments for JUL runs

Appendix G
MOBTOX5b Usage and Description

MOBTOX5b Input file

MOBTOX5b input file should be similar to the standard MOBILE5b input file with the following exceptions:

1. The NMHFLG should be set to 7. In addition the LTXFLG on the same record should always be 1. The format for the NMHFLG record should be : I1, 1x, I1. The input record should look like:

```
7 1       NMHFLG=7 for Toxics output.
```

2. The Toxic-TOG curves, the evaporative toxic fractions and the off-cycle correction factors are read in from three separate files. The input format of these files are described in Appendix I for the evaporative fractions, Appendix H for the toxic-TOG curves, and Appendix A for the off-cycle corrections. The input file needs to reference these files by using the following three statements:

```
TX EVP FRACTIONS : EVAPFILE.EVP
TX EXH FRACTIONS : TX-TOGFILE.EXH
OFFCYCLE FACTORS : OFFCYCLEFILE.OFF
```

The format of these lines need to have the exact format and content as described above on the left side of the colon. The colon should be in column 18. The file names on the right side of the colon should name the input files describing the toxic factors.

An example input and an output file are included in Appendices J and K, respectively. MOBTOX5b input prompts have been modified to ask the user for only the input file name. The model output is written to a file with the same name with a '.out' suffix.

MOBTOX5b General Description

There are primarily three areas where the model code has been changed, they are input, toxic factor calculations, and model output.

Model input:

The subroutine gettx2.for has been modified to read in the three files for evaporative, toxic-TOG corrections and off-cycle factors. These factors are then stored in a common block for use in other subroutines.

Toxic factor calculations:

The hccalx.for subroutine was modified to estimate emissions for each of the five toxic emission factors. The subroutine calls the exhaust emission calculation routine, bef.for, and evaporative emission calculation routines, ccevrt.for, rnglos.for, rstlos.for, and rlrate.for to calculate hot-soak and diurnal emissions, running loss emissions, resting loss emissions and refueling emissions.

The subroutine bef.for calls the subroutine toxadj.for to apply the toxic-TOG curves and offcyc.for to apply the offcycle corrections. The evaporative corrections are applied by a call to the evpadj.for subroutine from hccalx.for for each of the evaporative components.

Model output:

Two output subroutines OUTDT3 and OUTDT4 have been modified to include the toxic emission factors. A sample of the model output is attached. The output file contains all the toxic factors included in the input. Emission factors for Benzene, Acetaldehyde, Formaldehyde, 1,3 Butadiene, and MTBE are contained in the model output. For Benzene and MTBE evaporative and exhaust emission factors are included for each vehicle type.

Appendix H

Sample Toxic-TOG “Curves” for 1990 Phoenix Summertime Fuel

IV	MYA	MYB	TOG-N	TOG-H	BZ-N	BZ-H	AC-N	AC-H	FR-N	FR-H	BD-N	BD-H	MT-N	MT-H
1	1965	1974	0.000	10.00	0.00	464.70	0.00	59.34	0.00	221.52	0.00	90.98	0.00	0.00
1	1975	1975	0.000	10.00	0.00	464.92	0.00	49.08	0.00	163.84	0.00	53.03	0.00	0.00
1	1976	1977	0.000	10.00	0.00	464.94	0.00	48.43	0.00	160.24	0.00	50.66	0.00	0.00
1	1978	1979	0.000	10.00	0.00	464.95	0.00	47.79	0.00	156.63	0.00	48.28	0.00	0.00
1	1980	1980	0.000	10.00	0.00	464.97	0.00	47.15	0.00	153.02	0.00	45.91	0.00	0.00
1	1981	1981	0.640	4.03	39.58	193.31	2.46	15.98	6.84	41.46	2.54	33.19	0.00	0.00
1	1982	1982	0.628	4.03	36.99	192.96	2.46	16.15	6.91	42.61	2.51	32.23	0.00	0.00
1	1983	1983	0.628	4.03	36.52	193.61	2.41	15.84	6.64	40.49	2.49	33.99	0.00	0.00
1	1984	1984	0.639	4.03	37.86	195.09	2.33	15.12	6.08	35.62	2.48	38.04	0.00	0.00
1	1985	1985	0.644	4.03	35.83	194.95	2.38	15.19	6.25	36.09	2.53	37.65	0.00	0.00
1	1986	1986	0.641	4.03	34.12	195.36	2.33	14.98	6.09	34.73	2.53	38.78	0.00	0.00
1	1987	1987	0.612	4.03	31.65	195.42	2.26	14.96	5.85	34.54	2.41	38.93	0.00	0.00
1	1988	1988	0.570	4.03	27.37	195.55	2.14	14.89	5.52	34.10	2.27	39.30	0.00	0.00
1	1989	1989	0.557	4.03	27.36	195.53	2.10	14.90	5.43	34.18	2.24	39.23	0.00	0.00
1	1990	1990	0.535	4.03	24.71	195.55	2.05	14.89	5.29	34.13	2.17	39.28	0.00	0.00
1	1991	1991	0.514	4.03	23.61	195.55	2.00	14.89	5.13	34.10	2.09	39.30	0.00	0.00
1	1992	1992	0.519	4.03	23.91	195.53	2.01	14.90	5.20	34.18	2.13	39.23	0.00	0.00
1	1993	1993	0.498	4.03	23.01	195.55	1.96	14.89	5.02	34.10	2.03	39.30	0.00	0.00
1	1994	1994	0.500	4.03	23.17	195.55	1.97	14.89	5.04	34.10	2.05	39.30	0.00	0.00
1	1995	1995	0.332	4.03	15.40	195.55	1.31	14.89	3.35	34.10	1.36	39.30	0.00	0.00
1	1996	1999	0.332	4.03	15.42	195.55	1.31	14.89	3.35	34.10	1.36	39.30	0.00	0.00
1	2000	2000	0.332	4.03	15.42	195.55	1.31	14.89	3.35	34.10	1.36	39.30	0.00	0.00
1	2001	2003	0.117	4.03	4.72	195.55	0.40	14.89	1.02	34.10	0.42	39.30	0.00	0.00
1	2004	2050	0.117	4.03	4.72	195.55	0.40	14.89	1.02	34.10	0.42	39.30	0.00	0.00
2	1965	1974	0.000	10.00	0.00	464.70	0.00	59.34	0.00	221.52	0.00	90.98	0.00	0.00
2	1975	1975	0.000	10.00	0.00	464.90	0.00	50.36	0.00	171.05	0.00	57.77	0.00	0.00
2	1976	1976	0.000	10.00	0.00	464.92	0.00	49.08	0.00	163.84	0.00	53.03	0.00	0.00
2	1977	1978	0.000	10.00	0.00	464.91	0.00	49.72	0.00	167.45	0.00	55.40	0.00	0.00
2	1979	1980	0.000	10.00	0.00	464.92	0.00	49.08	0.00	163.84	0.00	53.03	0.00	0.00
2	1981	1981	0.638	4.03	29.95	187.71	2.98	18.85	9.60	60.68	2.86	18.53	0.00	0.00
2	1982	1982	0.638	4.03	30.28	187.88	2.94	18.61	9.38	59.26	2.76	18.41	0.00	0.00
2	1983	1983	0.636	4.03	31.63	188.63	2.88	18.38	9.12	57.55	2.80	20.95	0.00	0.00
2	1984	1984	0.627	4.03	33.09	189.74	2.72	17.71	8.36	53.16	2.64	23.48	0.00	0.00
2	1985	1985	0.593	4.03	31.57	190.53	2.53	17.33	7.60	50.56	2.47	25.63	0.00	0.00
2	1986	1986	0.572	4.03	28.45	191.60	2.40	16.81	7.00	47.06	2.37	28.54	0.00	0.00
2	1987	1987	0.648	4.03	31.38	193.45	2.49	15.91	7.06	41.01	2.65	33.56	0.00	0.00
2	1988	1988	0.620	4.03	29.28	195.16	2.28	15.08	6.09	35.41	2.49	38.21	0.00	0.00
2	1989	1989	0.653	4.03	30.44	195.44	2.33	14.95	6.25	34.47	2.64	38.99	0.00	0.00
2	1990	1990	0.623	4.03	28.24	195.45	2.25	14.95	6.03	34.47	2.53	39.03	0.00	0.00
2	1991	1991	0.595	4.03	26.95	195.55	2.18	14.89	5.76	34.13	2.40	39.28	0.00	0.00

2	1992	1992	0.562	4.03	25.55	195.45	2.10	14.97	5.57	34.59	2.30	39.10	0.00	0.00
2	1993	1993	0.556	4.03	25.37	195.55	2.08	14.89	5.46	34.10	2.26	39.30	0.00	0.00
2	1994	1994	0.554	4.03	25.15	195.55	2.08	14.89	5.46	34.10	2.26	39.30	0.00	0.00
2	1995	1995	0.368	4.03	16.72	195.55	1.38	14.89	3.62	34.10	1.50	39.30	0.00	0.00
2	1996	1996	0.373	4.03	16.92	195.55	1.39	14.89	3.66	34.10	1.52	39.30	0.00	0.00
2	1997	1997	0.370	4.03	16.83	195.55	1.39	14.89	3.64	34.10	1.51	39.30	0.00	0.00
2	1998	1998	0.367	4.03	16.73	195.55	1.38	14.89	3.62	34.10	1.50	39.30	0.00	0.00
2	1999	1999	0.364	4.03	16.64	195.55	1.38	14.89	3.59	34.10	1.49	39.30	0.00	0.00
2	2000	2000	0.361	4.03	16.54	195.55	1.37	14.89	3.57	34.10	1.48	39.30	0.00	0.00
2	2001	2003	0.126	4.03	5.38	195.55	0.45	14.89	1.16	34.10	0.48	39.30	0.00	0.00
2	2004	2050	0.126	4.03	5.38	195.55	0.45	14.89	1.16	34.10	0.48	39.30	0.00	0.00
3	1965	1978	0.000	10.00	0.00	464.70	0.00	59.34	0.00	221.52	0.00	90.98	0.00	0.00
3	1979	1980	0.000	10.00	0.00	464.98	0.00	46.51	0.00	149.42	0.00	43.54	0.00	0.00
3	1981	1981	0.638	4.03	29.95	187.71	2.98	18.85	9.60	60.68	2.86	18.53	0.00	0.00
3	1982	1982	0.638	4.03	30.28	187.88	2.94	18.61	9.38	59.26	2.76	18.41	0.00	0.00
3	1983	1983	0.636	4.03	31.63	188.63	2.88	18.38	9.12	57.55	2.80	20.95	0.00	0.00
3	1984	1984	0.627	4.03	33.09	189.74	2.72	17.71	8.36	53.16	2.64	23.48	0.00	0.00
3	1985	1985	0.593	4.03	31.57	190.53	2.53	17.33	7.60	50.56	2.47	25.63	0.00	0.00
3	1986	1986	0.572	4.03	28.45	191.60	2.40	16.81	7.00	47.06	2.37	28.54	0.00	0.00
3	1987	1987	0.648	4.03	31.38	193.45	2.49	15.91	7.06	41.01	2.65	33.56	0.00	0.00
3	1988	1988	0.620	4.03	29.28	195.16	2.28	15.08	6.09	35.41	2.49	38.21	0.00	0.00
3	1989	1989	0.653	4.03	30.44	195.44	2.33	14.95	6.25	34.47	2.64	38.99	0.00	0.00
3	1990	1990	0.623	4.03	28.24	195.45	2.25	14.95	6.03	34.47	2.53	39.03	0.00	0.00
3	1991	1991	0.595	4.03	26.95	195.55	2.18	14.89	5.76	34.13	2.40	39.28	0.00	0.00
3	1992	1992	0.562	4.03	25.55	195.45	2.10	14.97	5.57	34.59	2.30	39.10	0.00	0.00
3	1993	1993	0.556	4.03	25.37	195.55	2.08	14.89	5.46	34.10	2.26	39.30	0.00	0.00
3	1994	1994	0.554	4.03	25.15	195.55	2.08	14.89	5.46	34.10	2.26	39.30	0.00	0.00
3	1995	1995	0.555	4.03	25.21	195.55	2.08	14.89	5.46	34.10	2.26	39.30	0.00	0.00
3	1996	1996	0.563	4.03	25.52	195.55	2.10	14.89	5.52	34.10	2.29	39.30	0.00	0.00
3	1997	1997	0.370	4.03	16.83	195.55	1.39	14.89	3.64	34.10	1.51	39.30	0.00	0.00
3	1998	1998	0.367	4.03	16.73	195.55	1.38	14.89	3.62	34.10	1.50	39.30	0.00	0.00
3	1999	1999	0.364	4.03	16.64	195.55	1.38	14.89	3.59	34.10	1.49	39.30	0.00	0.00
3	2000	2000	0.361	4.03	16.54	195.55	1.37	14.89	3.57	34.10	1.48	39.30	0.00	0.00
3	2001	2003	0.357	4.03	16.45	195.55	1.37	14.89	3.55	34.10	1.47	39.30	0.00	0.00
3	2004	2050	0.357	4.03	16.45	195.55	1.37	14.89	3.55	34.10	1.47	39.30	0.00	0.00
4	1968	1981	0.000	10.00	0.00	464.70	0.00	66.26	0.00	343.16	0.00	73.18	0.00	0.00
4	1982	1986	0.000	10.00	0.00	470.08	0.00	65.27	0.00	333.47	0.00	70.96	0.00	0.00
4	1987	1987	0.000	10.00	0.00	496.95	0.00	60.33	0.00	285.04	0.00	59.84	0.00	0.00
4	1988	1989	0.000	10.00	0.00	507.70	0.00	58.36	0.00	265.66	0.00	55.39	0.00	0.00
4	1990	1995	0.000	10.00	0.00	564.68	0.00	47.89	0.00	162.98	0.00	31.81	0.00	0.00
4	1996	1999	0.000	10.00	0.00	566.83	0.00	47.50	0.00	159.11	0.00	30.92	0.00	0.00

4	2000	2000	0.000	10.00	0.00	570.06	0.00	46.90	0.00	153.29	0.00	29.59	0.00	0.00
4	2001	2004	0.000	10.00	0.00	570.06	0.00	46.90	0.00	153.29	0.00	29.59	0.00	0.00
4	2005	2020	0.000	10.00	0.00	572.21	0.00	46.51	0.00	149.42	0.00	28.70	0.00	0.00
5	1965	2050	0.000	10.00	0.00	200.00	0.00	123.00	0.00	386.00	0.00	90.00	0.00	0.00
6	1965	2050	0.000	10.00	0.00	200.00	0.00	123.00	0.00	386.00	0.00	90.00	0.00	0.00
7	1965	2050	0.000	10.00	0.00	105.00	0.00	288.00	0.00	782.00	0.00	61.00	0.00	0.00
8	1965	2020	0.000	10.00	0.00	464.70	0.00	59.34	0.00	221.52	0.00	90.98	0.00	0.00

Appendix I

Sample Evaporative Fraction Input File for 1990 Phoenix Summertime Fuel

PX90SB.EVP - Phoenix 1990 Summer Baseline Evap Fractions
1
2050

0.0171	0.0156	0.0158	0.0171	0.0156	0.0171	0.0156	0.0158	0.0171	0.0156
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Appendix J

Sample T2ATTOX Input File For Phoenix

```
1          PROMPT - No prompting, vertical
MOBTOX5 -- PX90SB.INP
1          TAMFLG - Default tampering rates
1          SPDFLG - One speed per scenario
1          VMFLAG - Default VMT mix
3          MYMRFG - Input registration distributions
2          NEWFLG - Input new exhaust emission rates
3          IMFLAG - Two I/M programs
1          ALHFLG - No corrections
2          ATPFLG - ATP
1          RLFLAG - Refueling with onboard VRS
1          LOCFLG - One LAP record for each scenario
1          TEMFLG - Use default ambient exhaust temperatures
3          OUTFMT - 112-column descriptive
1          PRTFLG - Output HC only
1          IDLFLG - Do not output idle EFs
7 1        NMHFLG
2          HCFLAG - Component and total EFs printed
 .048 .079 .083 .082 .084 .081 .078 .056 .050 .051
 .050 .054 .047 .037 .024 .019 .018 .017 .013 .008
 .007 .005 .004 .003 .002       ldgv
 .057 .097 .099 .094 .098 .082 .070 .039 .033 .029
 .026 .041 .030 .028 .024 .020 .026 .025 .021 .014
 .012 .012 .009 .007 .007       ldgt1
 .044 .074 .073 .058 .066 .060 .058 .051 .041 .039
 .038 .079 .083 .065 .043 .031 .021 .020 .015 .010
 .009 .008 .006 .004 .004       ldgt2
 .026 .049 .055 .042 .041 .030 .029 .023 .022 .028
 .035 .072 .074 .061 .053 .038 .060 .051 .046 .032
 .036 .037 .024 .025 .011       hdgv
 .048 .079 .083 .082 .084 .081 .078 .056 .050 .051
 .050 .054 .047 .037 .024 .019 .018 .017 .013 .008
 .007 .005 .004 .003 .002       lddv
 .057 .097 .099 .094 .098 .082 .070 .039 .033 .029
 .026 .041 .030 .028 .024 .020 .026 .025 .021 .014
 .012 .012 .009 .007 .007       lddt
 .051 .091 .090 .078 .079 .087 .090 .049 .042 .039
 .030 .052 .038 .031 .018 .012 .026 .022 .019 .012
 .012 .012 .008 .006 .006       hddv
 .133 .152 .149 .115 .083 .080 .065 .049 .033 .029
 .022 .090 .000 .000 .000 .000 .000 .000 .000 .000
 .000 .000 .000 .000 .000       mc
0099           ZM    DR1    DR2 Flex Pt  File: NTR_IM_B.BER
1 1 1 65 67  7.488  0.186                      LDGV
1 1 1 68 69  4.576  0.258
1 1 1 70 71  3.099  0.382
1 1 1 72 74  3.491  0.165
```

```
1 1 1 75 75  1.068  0.282
1 1 1 76 77  1.071  0.283
1 1 1 78 79  1.074  0.284
1 1 1 80 80  0.371  0.211
1 1 1 81 82  0.398  0.149  0.209   1.53
1 1 1 83 83  0.258  0.051  0.140   2.22
1 1 1 84 84  0.257  0.051  0.140   2.22
1 1 1 85 85  0.251  0.050  0.137   2.22
1 1 1 86 86  0.303  0.058
1 1 1 87 87  0.299  0.057
1 1 1 88 88  0.290  0.056
1 1 1 89 89  0.288  0.055
1 1 1 90 90  0.200  0.019  0.040   2.13
1 1 1 91 91  0.198  0.018  0.040   2.13
1 1 1 92 92  0.197  0.018  0.040   2.13
1 1 1 93 94  0.195  0.018  0.040   2.13
1 1 1 95 00  0.169  0.011  0.022   8.90
1 1 1 01 03  0.094  0.009  0.015   7.87        Includes LEV Sulfur Corr    1.36
1 1 1 04 50  0.094  0.009  0.015   7.87        Includes LEV Sulfur Corr    1.36
1 2 1 65 67  7.488  0.186                      LDGT1
1 2 1 68 69  4.576  0.258
1 2 1 70 71  3.099  0.382
1 2 1 72 74  3.470  0.176
1 2 1 75 75  1.802  0.270
1 2 1 76 76  1.813  0.272
1 2 1 77 78  1.807  0.271
1 2 1 79 80  0.876  0.282
1 2 1 81 82  1.140  0.044  0.143   1.73
1 2 1 83 83  1.156  0.045  0.145   1.73
1 2 1 84 84  0.486  0.022  0.108   4.41
1 2 1 85 85  0.483  0.022  0.107   4.41
1 2 1 86 86  0.477  0.022  0.106   4.41
1 2 1 87 87  0.487  0.022  0.108   4.41
1 2 1 88 88  0.486  0.022  0.108   4.41
1 2 1 89 89  0.491  0.022  0.109   4.41
1 2 1 90 90  0.323  0.018  0.047   2.13
1 2 1 91 91  0.306  0.017  0.044   2.13
1 2 1 92 93  0.318  0.017  0.046   2.13
1 2 1 94 94  0.317  0.017  0.046   2.13
1 2 1 95 00  0.214  0.012  0.025   9.06
1 2 1 01 03  0.110  0.008  0.016   8.29        Includes LEV Sulfur Corr    1.23
1 2 1 04 50  0.110  0.008  0.016   8.29        Includes LEV Sulfur Corr    1.23
1 3 1 65 69  9.885  0.186                      LDGT2
1 3 1 70 73  6.486  0.258
1 3 1 74 78  6.486  0.176
1 3 1 79 80  0.887  0.286
1 3 1 81 82  1.139  0.044  0.143   1.73
```

1	3	1	83	83	1.159	0.045	0.146	1.73	
1	3	1	84	84	0.492	0.022	0.109	4.41	
1	3	1	85	85	0.500	0.023	0.111	4.41	
1	3	1	86	86	0.509	0.023	0.113	4.41	
1	3	1	87	87	0.513	0.023	0.114	4.41	
1	3	1	88	88	0.508	0.023	0.113	4.41	
1	3	1	89	89	0.508	0.023	0.113	4.41	
1	3	1	90	90	0.340	0.019	0.049	2.13	
1	3	1	91	91	0.306	0.017	0.044	2.13	
1	3	1	92	93	0.318	0.017	0.046	2.13	
1	3	1	94	95	0.317	0.017	0.046	2.13	
1	3	1	96	96	0.318	0.017	0.046	2.13	
1	3	1	97	00	0.260	0.012	0.030	9.25	
1	3	1	01	03	0.258	0.012	0.030	9.25	
1	3	1	04	50	0.258	0.012	0.030	9.25	
1	4	1	94	94	0.586	0.037			HDGV
1	4	1	95	95	0.586	0.037			
1	4	1	96	96	0.589	0.037			
1	4	1	97	97	0.589	0.037			
1	4	1	98	98	0.589	0.037			
1	4	1	99	99	0.589	0.037			
1	4	1	00	00	0.593	0.037			
1	4	1	01	01	0.593	0.037			
1	4	1	02	02	0.593	0.037			
1	4	1	03	03	0.593	0.037			
1	4	1	04	50	0.453	0.029			
1	5	1	95	95	0.161	0.011	0.021	8.90	LDDV
1	5	1	96	96	0.161	0.011	0.021	8.90	
1	5	1	97	97	0.161	0.011	0.021	8.90	
1	5	1	98	98	0.161	0.011	0.021	8.90	
1	5	1	99	99	0.161	0.011	0.021	8.90	
1	5	1	00	00	0.161	0.011	0.021	8.90	
1	5	1	01	01	0.066	0.006	0.011	7.87	
1	5	1	02	02	0.066	0.006	0.011	7.87	
1	5	1	03	03	0.066	0.006	0.011	7.87	
1	5	1	04	50	0.066	0.006	0.011	7.87	
1	6	1	95	95	0.271	0.015	0.038	3.87	LDDT Assumes 25% LDT1 and 75% LDT2
1	6	1	96	96	0.271	0.015	0.038	3.87	
1	6	1	97	97	0.231	0.011	0.027	9.21	
1	6	1	98	98	0.231	0.011	0.027	9.21	
1	6	1	99	99	0.231	0.011	0.027	9.21	
1	6	1	00	00	0.231	0.011	0.027	9.21	
1	6	1	01	01	0.202	0.010	0.024	9.01	
1	6	1	02	02	0.202	0.010	0.024	9.01	
1	6	1	03	03	0.202	0.010	0.024	9.01	
1	6	1	04	50	0.202	0.010	0.024	9.01	
1	7	1	94	03	0.320	0.000			HDDV

```
1 7 1 04 50  0.290  0.000
78 31 67 80 08 08 096 111 2222 1111
78 31 81 94 08 08 096 111 2222 1111
88 67 50 2222 11  096 22221111
TX EVP FRACTIONS : EVP\PX90SB.EVP
TX EXH EMISSIONS : EXH\PX90SB_B.EXH
OFFCYCLE FACTORS : OFF\IM90.OFF
1 90 19.6 76.2 20.6 27.3 20.6  7
PX90SB.INP Spr   B 064. 088. 08.1 08.1 20 1 1 2 1
1 90 19.6 93.6 20.6 27.3 20.6  7
PX90SB.INP Sum   B 083. 105. 08.1 08.1 20 1 1 2 1
```

Appendix K

Sample T2ATTOX Output For Phoenix

1MOBTOX5 -- PX90SB.INP
M5TOXRAD based on Mobile5b(27FEB98)Mods by Radian 7/98
Reading I/M credits information
Annual Idle Only 220/1.2 Cutpoints IDLE.IMC

Evap Toxic emission frac. data read from file : EVP\PX90SB.EVP

Exhaust Toxic emission data read from file : EXH\PX90SB_B.EXH

Off Cycle data read from file : OFF\IM90.OFF

EVP\PX90SB.EVP : PX90SB.EVP - Phoenix 1990 Summer Baseline Evap Fractions

EXH\PX90SB_B.EXH : IV MYA MYB TOG-N TOG-H BZ-N BZ-H AC-N AC-H FR-N

OFF\IM90.OFF : Off-Cycle Corrections - I/M 1990 UC/FTP Toxics Mass Fraction Ratios

Benzene & TOG Emissions for LDGVs from files : EXH\PX90SB_B.EX EVP\PX90SB.EVP OFF\IM90.OFF

Year	TX-Lo	TX-Hi	TOG-Hi	TOG-Lo	TXEVHS	TXEVDI	TXEVRF	TXEVRN	EVPTXRST	AGG	A/C	AGG-TOX
1965	0.000	464.700	0.000	10.000	0.017	0.016	0.016	0.017	0.016	1.079	1.016	1.000
1966	0.000	464.700	0.000	10.000	0.017	0.016	0.016	0.017	0.016	1.079	1.016	1.000
1967	0.000	464.700	0.000	10.000	0.017	0.016	0.016	0.017	0.016	1.078	1.015	1.000
1968	0.000	464.700	0.000	10.000	0.017	0.016	0.016	0.017	0.016	1.090	1.018	1.000
1969	0.000	464.700	0.000	10.000	0.017	0.016	0.016	0.017	0.016	1.089	1.017	1.000
1970	0.000	464.700	0.000	10.000	0.017	0.016	0.016	0.017	0.016	1.081	1.016	1.000
1971	0.000	464.700	0.000	10.000	0.017	0.016	0.016	0.017	0.016	1.081	1.016	1.000
1972	0.000	464.700	0.000	10.000	0.017	0.016	0.016	0.017	0.016	1.122	1.023	1.000
1973	0.000	464.700	0.000	10.000	0.017	0.016	0.016	0.017	0.016	1.120	1.023	1.000
1974	0.000	464.700	0.000	10.000	0.017	0.016	0.016	0.017	0.016	1.118	1.023	1.000
1975	0.000	464.920	0.000	10.000	0.017	0.016	0.016	0.017	0.016	1.137	1.026	1.000
1976	0.000	464.940	0.000	10.000	0.017	0.016	0.016	0.017	0.016	1.137	1.026	1.000
1977	0.000	464.940	0.000	10.000	0.017	0.016	0.016	0.017	0.016	1.136	1.026	1.000
1978	0.000	464.950	0.000	10.000	0.017	0.016	0.016	0.017	0.016	1.135	1.026	1.000
1979	0.000	464.950	0.000	10.000	0.017	0.016	0.016	0.017	0.016	1.135	1.025	1.000
1980	0.000	464.970	0.000	10.000	0.017	0.016	0.016	0.017	0.016	1.211	1.037	1.000
1981	39.580	193.310	0.640	4.030	0.017	0.016	0.016	0.017	0.016	1.230	1.040	1.126
1982	36.990	192.960	0.628	4.030	0.017	0.016	0.016	0.017	0.016	1.230	1.040	1.128
1983	36.520	193.610	0.628	4.030	0.017	0.016	0.016	0.017	0.016	1.230	1.040	1.156
1984	37.860	195.090	0.639	4.030	0.017	0.016	0.016	0.017	0.016	1.230	1.040	1.165
1985	35.830	194.950	0.644	4.030	0.017	0.016	0.016	0.017	0.016	1.230	1.040	1.175
1986	34.120	195.360	0.641	4.030	0.017	0.016	0.016	0.017	0.016	1.230	1.040	1.213
1987	31.650	195.420	0.612	4.030	0.017	0.016	0.016	0.017	0.016	1.230	1.040	1.228
1988	27.370	195.550	0.570	4.030	0.017	0.016	0.016	0.017	0.016	1.230	1.040	1.247
1989	27.360	195.530	0.557	4.030	0.017	0.016	0.016	0.017	0.016	1.230	1.040	1.273
1990	24.710	195.550	0.535	4.030	0.017	0.016	0.016	0.017	0.016	1.230	1.040	1.315
1991	23.610	195.550	0.514	4.030	0.017	0.016	0.016	0.017	0.016	1.230	1.040	1.315
1992	23.910	195.530	0.519	4.030	0.017	0.016	0.016	0.017	0.016	1.230	1.040	1.315

1993	23.010	195.550	0.498	4.030	0.017	0.016	0.016	0.017	0.016	1.230	1.040	1.315
1994	23.170	195.550	0.500	4.030	0.017	0.016	0.016	0.017	0.016	1.230	1.040	1.315
1995	15.400	195.550	0.332	4.030	0.017	0.016	0.016	0.017	0.016	1.290	1.010	1.315
1996	15.420	195.550	0.332	4.030	0.017	0.016	0.016	0.017	0.016	1.290	1.010	1.315
1997	15.420	195.550	0.332	4.030	0.017	0.016	0.016	0.017	0.016	1.290	1.010	1.315
1998	15.420	195.550	0.332	4.030	0.017	0.016	0.016	0.017	0.016	1.290	1.010	1.315
1999	15.420	195.550	0.332	4.030	0.017	0.016	0.016	0.017	0.016	1.290	1.010	1.315
2000	15.420	195.550	0.332	4.030	0.017	0.016	0.016	0.017	0.016	1.290	1.010	1.315
2001	4.720	195.550	0.117	4.030	0.017	0.016	0.016	0.017	0.016	1.220	1.003	1.315
2002	4.720	195.550	0.117	4.030	0.017	0.016	0.016	0.017	0.016	1.150	0.995	1.315
2003	4.720	195.550	0.117	4.030	0.017	0.016	0.016	0.017	0.016	1.052	0.985	1.315
2004	4.720	195.550	0.117	4.030	0.017	0.016	0.016	0.017	0.016	1.010	0.980	1.315
2005	4.720	195.550	0.117	4.030	0.017	0.016	0.016	0.017	0.016	1.010	0.980	1.315
2006	4.720	195.550	0.117	4.030	0.017	0.016	0.016	0.017	0.016	1.010	0.980	1.315
2007	4.720	195.550	0.117	4.030	0.017	0.016	0.016	0.017	0.016	1.010	0.980	1.315
2008	4.720	195.550	0.117	4.030	0.017	0.016	0.016	0.017	0.016	1.010	0.980	1.315
2009	4.720	195.550	0.117	4.030	0.017	0.016	0.016	0.017	0.016	1.010	0.980	1.315
2010	4.720	195.550	0.117	4.030	0.017	0.016	0.016	0.017	0.016	1.010	0.980	1.315
2011	4.720	195.550	0.117	4.030	0.017	0.016	0.016	0.017	0.016	1.010	0.980	1.315
2012	4.720	195.550	0.117	4.030	0.017	0.016	0.016	0.017	0.016	1.010	0.980	1.315
2013	4.720	195.550	0.117	4.030	0.017	0.016	0.016	0.017	0.016	1.010	0.980	1.315
2014	4.720	195.550	0.117	4.030	0.017	0.016	0.016	0.017	0.016	1.010	0.980	1.315
2015	4.720	195.550	0.117	4.030	0.017	0.016	0.016	0.017	0.016	1.010	0.980	1.315
2016	4.720	195.550	0.117	4.030	0.017	0.016	0.016	0.017	0.016	1.010	0.980	1.315
2017	4.720	195.550	0.117	4.030	0.017	0.016	0.016	0.017	0.016	1.010	0.980	1.315
2018	4.720	195.550	0.117	4.030	0.017	0.016	0.016	0.017	0.016	1.010	0.980	1.315
2019	4.720	195.550	0.117	4.030	0.017	0.016	0.016	0.017	0.016	1.010	0.980	1.315
2020	4.720	195.550	0.117	4.030	0.017	0.016	0.016	0.017	0.016	1.010	0.980	1.315

Acetaldehyde & TOG Emissions for LDGVs from file : EXH\PX90SB_B.EX OFF\IM90.OFF

Year	TX-Lo	TX-Hi	TOG-Hi	TOG-Lo	AGG	A/C	AGG-TOX
1965	0.000	59.340	0.000	10.000	1.048	1.002	1.000
1966	0.000	59.340	0.000	10.000	1.048	1.002	1.000
1967	0.000	59.340	0.000	10.000	1.048	1.002	1.000
1968	0.000	59.340	0.000	10.000	1.055	1.003	1.000
1969	0.000	59.340	0.000	10.000	1.055	1.003	1.000
1970	0.000	59.340	0.000	10.000	1.050	1.003	1.000
1971	0.000	59.340	0.000	10.000	1.050	1.003	1.000
1972	0.000	59.340	0.000	10.000	1.074	1.004	1.000
1973	0.000	59.340	0.000	10.000	1.074	1.004	1.000
1974	0.000	59.340	0.000	10.000	1.073	1.004	1.000
1975	0.000	49.080	0.000	10.000	1.078	1.004	1.000
1976	0.000	48.430	0.000	10.000	1.078	1.004	1.000
1977	0.000	48.430	0.000	10.000	1.077	1.004	1.000
1978	0.000	47.790	0.000	10.000	1.077	1.004	1.000
1979	0.000	47.790	0.000	10.000	1.091	1.004	1.000
1980	0.000	47.150	0.000	10.000	1.091	1.004	1.000
1981	2.460	15.980	0.640	4.030	1.258	1.011	0.919
1982	2.460	16.150	0.628	4.030	1.249	1.011	0.920
1983	2.410	15.840	0.628	4.030	1.238	1.010	0.935

1984	2.330	15.120	0.639	4.030	1.230	1.010	0.940
1985	2.380	15.190	0.644	4.030	1.230	1.010	0.945
1986	2.330	14.980	0.641	4.030	1.230	1.010	0.966
1987	2.260	14.960	0.612	4.030	1.230	1.010	0.973
1988	2.140	14.890	0.570	4.030	1.230	1.010	0.983
1989	2.100	14.900	0.557	4.030	1.230	1.010	0.997
1990	2.050	14.890	0.535	4.030	1.230	1.010	1.020
1991	2.000	14.890	0.514	4.030	1.230	1.010	1.020
1992	2.010	14.900	0.519	4.030	1.230	1.010	1.020
1993	1.960	14.890	0.498	4.030	1.230	1.010	1.020
1994	1.970	14.890	0.500	4.030	1.230	1.010	1.020
1995	1.310	14.890	0.332	4.030	1.290	1.010	1.020
1996	1.310	14.890	0.332	4.030	1.290	1.010	1.020
1997	1.310	14.890	0.332	4.030	1.290	1.010	1.020
1998	1.310	14.890	0.332	4.030	1.290	1.010	1.020
1999	1.310	14.890	0.332	4.030	1.290	1.010	1.020
2000	1.310	14.890	0.332	4.030	1.290	1.010	1.020
2001	0.400	14.890	0.117	4.030	1.223	1.008	1.020
2002	0.400	14.890	0.117	4.030	1.155	1.005	1.020
2003	0.400	14.890	0.117	4.030	1.061	1.002	1.020
2004	0.400	14.890	0.117	4.030	1.020	1.000	1.020
2005	0.400	14.890	0.117	4.030	1.020	1.000	1.020
2006	0.400	14.890	0.117	4.030	1.020	1.000	1.020
2007	0.400	14.890	0.117	4.030	1.020	1.000	1.020
2008	0.400	14.890	0.117	4.030	1.020	1.000	1.020
2009	0.400	14.890	0.117	4.030	1.020	1.000	1.020
2010	0.400	14.890	0.117	4.030	1.020	1.000	1.020
2011	0.400	14.890	0.117	4.030	1.020	1.000	1.020
2012	0.400	14.890	0.117	4.030	1.020	1.000	1.020
2013	0.400	14.890	0.117	4.030	1.020	1.000	1.020
2014	0.400	14.890	0.117	4.030	1.020	1.000	1.020
2015	0.400	14.890	0.117	4.030	1.020	1.000	1.020
2016	0.400	14.890	0.117	4.030	1.020	1.000	1.020
2017	0.400	14.890	0.117	4.030	1.020	1.000	1.020
2018	0.400	14.890	0.117	4.030	1.020	1.000	1.020
2019	0.400	14.890	0.117	4.030	1.020	1.000	1.020
2020	0.400	14.890	0.117	4.030	1.020	1.000	1.020

Formaldehyde & TOG Emissions for LDGVs from file : EXH\PX90SB_B.EX OFF\IM90.OFF

Year	TX-Lo	TX-Hi	TOG-Hi	TOG-Lo	AGG	A/C	AGG-TOX
1965	0.000	221.520	0.000	10.000	1.044	0.998	1.000
1966	0.000	221.520	0.000	10.000	1.044	0.998	1.000
1967	0.000	221.520	0.000	10.000	1.044	0.998	1.000
1968	0.000	221.520	0.000	10.000	1.043	0.998	1.000
1969	0.000	221.520	0.000	10.000	1.042	0.998	1.000
1970	0.000	221.520	0.000	10.000	1.048	0.998	1.000
1971	0.000	221.520	0.000	10.000	1.047	0.998	1.000
1972	0.000	221.520	0.000	10.000	1.047	0.998	1.000
1973	0.000	221.520	0.000	10.000	1.046	0.998	1.000
1974	0.000	221.520	0.000	10.000	1.052	0.997	1.000

1975	0.000	163.840	0.000	10.000	1.051	0.997	1.000
1976	0.000	160.240	0.000	10.000	1.050	0.997	1.000
1977	0.000	160.240	0.000	10.000	1.048	0.998	1.000
1978	0.000	156.630	0.000	10.000	1.047	0.998	1.000
1979	0.000	156.630	0.000	10.000	1.090	0.996	1.000
1980	0.000	153.020	0.000	10.000	1.091	0.996	1.000
1981	6.840	41.460	0.640	4.030	1.264	0.989	0.894
1982	6.910	42.610	0.628	4.030	1.253	0.989	0.897
1983	6.640	40.490	0.628	4.030	1.241	0.990	0.936
1984	6.080	35.620	0.639	4.030	1.230	0.990	0.949
1985	6.250	36.090	0.644	4.030	1.230	0.990	0.964
1986	6.090	34.730	0.641	4.030	1.230	0.990	1.018
1987	5.850	34.540	0.612	4.030	1.230	0.990	1.039
1988	5.520	34.100	0.570	4.030	1.230	0.990	1.066
1989	5.430	34.180	0.557	4.030	1.230	0.990	1.103
1990	5.290	34.130	0.535	4.030	1.230	0.990	1.163
1991	5.130	34.100	0.514	4.030	1.230	0.990	1.163
1992	5.200	34.180	0.519	4.030	1.230	0.990	1.163
1993	5.020	34.100	0.498	4.030	1.230	0.990	1.163
1994	5.040	34.100	0.500	4.030	1.230	0.990	1.163
1995	3.350	34.100	0.332	4.030	1.230	0.990	1.163
1996	3.350	34.100	0.332	4.030	1.230	0.990	1.163
1997	3.350	34.100	0.332	4.030	1.290	1.000	1.163
1998	3.350	34.100	0.332	4.030	1.290	1.000	1.163
1999	3.350	34.100	0.332	4.030	1.290	1.000	1.163
2000	3.350	34.100	0.332	4.030	1.290	1.000	1.163
2001	1.020	34.100	0.117	4.030	1.290	1.000	1.163
2002	1.020	34.100	0.117	4.030	1.190	1.000	1.163
2003	1.020	34.100	0.117	4.030	1.090	1.000	1.163
2004	1.020	34.100	0.117	4.030	1.040	1.000	1.163
2005	1.020	34.100	0.117	4.030	1.040	1.000	1.163
2006	1.020	34.100	0.117	4.030	1.040	1.000	1.163
2007	1.020	34.100	0.117	4.030	1.040	1.000	1.163
2008	1.020	34.100	0.117	4.030	1.040	1.000	1.163
2009	1.020	34.100	0.117	4.030	1.040	1.000	1.163
2010	1.020	34.100	0.117	4.030	1.040	1.000	1.163
2011	1.020	34.100	0.117	4.030	1.040	1.000	1.163
2012	1.020	34.100	0.117	4.030	1.040	1.000	1.163
2013	1.020	34.100	0.117	4.030	1.040	1.000	1.163
2014	1.020	34.100	0.117	4.030	1.040	1.000	1.163
2015	1.020	34.100	0.117	4.030	1.040	1.000	1.163
2016	1.020	34.100	0.117	4.030	1.040	1.000	1.163
2017	1.020	34.100	0.117	4.030	1.040	1.000	1.163
2018	1.020	34.100	0.117	4.030	1.040	1.000	1.163
2019	1.020	34.100	0.117	4.030	1.040	1.000	1.163
2020	1.020	34.100	0.117	4.030	1.040	1.000	1.163

1,3 Butadiene & TOG Emissions for LDGVs from file : EXH\PX90SB_B.EX OFF\IM90.OFF

Year	TX-Lo	TX-Hi	TOG-Hi	TOG-Lo	AGG	A/C	AGG-TOX
1965	0.000	90.980	0.000	10.000	1.000	1.000	1.000

Sample Output File

1966	0.000	90.980	0.000	10.000	1.000	1.000	1.000
1967	0.000	90.980	0.000	10.000	1.000	1.000	1.000
1968	0.000	90.980	0.000	10.000	1.000	1.000	1.000
1969	0.000	90.980	0.000	10.000	1.000	1.000	1.000
1970	0.000	90.980	0.000	10.000	1.000	1.000	1.000
1971	0.000	90.980	0.000	10.000	1.000	1.000	1.000
1972	0.000	90.980	0.000	10.000	1.000	1.000	1.000
1973	0.000	90.980	0.000	10.000	1.000	1.000	1.000
1974	0.000	90.980	0.000	10.000	1.000	1.000	1.000
1975	0.000	53.030	0.000	10.000	1.000	1.000	1.000
1976	0.000	50.660	0.000	10.000	1.000	1.000	1.000
1977	0.000	50.660	0.000	10.000	1.000	1.000	1.000
1978	0.000	48.280	0.000	10.000	1.000	1.000	1.000
1979	0.000	48.280	0.000	10.000	1.000	1.000	1.000
1980	0.000	45.910	0.000	10.000	1.000	1.000	1.000
1981	2.540	33.190	0.640	4.030	1.000	1.000	0.708
1982	2.510	32.230	0.628	4.030	1.000	1.000	0.712
1983	2.490	33.990	0.628	4.030	1.000	1.000	0.760
1984	2.480	38.040	0.639	4.030	1.000	1.000	0.776
1985	2.530	37.650	0.644	4.030	1.000	1.000	0.793
1986	2.530	38.780	0.641	4.030	1.000	1.000	0.860
1987	2.410	38.930	0.612	4.030	1.000	1.000	0.885
1988	2.270	39.300	0.570	4.030	1.000	1.000	0.918
1989	2.240	39.230	0.557	4.030	1.000	1.000	0.963
1990	2.170	39.280	0.535	4.030	1.000	1.000	1.037
1991	2.090	39.300	0.514	4.030	1.000	1.000	1.037
1992	2.130	39.230	0.519	4.030	1.000	1.000	1.037
1993	2.030	39.300	0.498	4.030	1.000	1.000	1.037
1994	2.050	39.300	0.500	4.030	1.000	1.000	1.037
1995	1.360	39.300	0.332	4.030	1.000	1.000	1.037
1996	1.360	39.300	0.332	4.030	1.000	1.000	1.037
1997	1.360	39.300	0.332	4.030	1.000	1.000	1.037
1998	1.360	39.300	0.332	4.030	1.000	1.000	1.037
1999	1.360	39.300	0.332	4.030	1.000	1.000	1.037
2000	1.360	39.300	0.332	4.030	1.000	1.000	1.037
2001	0.420	39.300	0.117	4.030	1.000	1.000	1.037
2002	0.420	39.300	0.117	4.030	1.000	1.000	1.037
2003	0.420	39.300	0.117	4.030	1.000	1.000	1.037
2004	0.420	39.300	0.117	4.030	1.000	1.000	1.037
2005	0.420	39.300	0.117	4.030	1.000	1.000	1.037
2006	0.420	39.300	0.117	4.030	1.000	1.000	1.037
2007	0.420	39.300	0.117	4.030	1.000	1.000	1.037
2008	0.420	39.300	0.117	4.030	1.000	1.000	1.037
2009	0.420	39.300	0.117	4.030	1.000	1.000	1.037
2010	0.420	39.300	0.117	4.030	1.000	1.000	1.037
2011	0.420	39.300	0.117	4.030	1.000	1.000	1.037
2012	0.420	39.300	0.117	4.030	1.000	1.000	1.037
2013	0.420	39.300	0.117	4.030	1.000	1.000	1.037
2014	0.420	39.300	0.117	4.030	1.000	1.000	1.037
2015	0.420	39.300	0.117	4.030	1.000	1.000	1.037

2016	0.420	39.300	0.117	4.030	1.000	1.000	1.037
2017	0.420	39.300	0.117	4.030	1.000	1.000	1.037
2018	0.420	39.300	0.117	4.030	1.000	1.000	1.037
2019	0.420	39.300	0.117	4.030	1.000	1.000	1.037
2020	0.420	39.300	0.117	4.030	1.000	1.000	1.037

MTBE & TOG Emissions for LDGVs from files : EXH\PX90SB_B.EX EVP\PX90SB.EVP OFF\IM90.OFF

Year	TX-Lo	TX-Hi	TOG-Hi	TOG-Lo	TXEVHS	TXEVDI	TXEVRF	TXEVRN	EVPTXRST	AGG	A/C	AGG-TOX
1965	0.000	0.000	0.000	10.000	0.017	0.016	0.016	0.017	0.016	1.079	1.016	1.000
1966	0.000	0.000	0.000	10.000	0.017	0.016	0.016	0.017	0.016	1.079	1.016	1.000
1967	0.000	0.000	0.000	10.000	0.017	0.016	0.016	0.017	0.016	1.078	1.015	1.000
1968	0.000	0.000	0.000	10.000	0.017	0.016	0.016	0.017	0.016	1.090	1.018	1.000
1969	0.000	0.000	0.000	10.000	0.017	0.016	0.016	0.017	0.016	1.089	1.017	1.000
1970	0.000	0.000	0.000	10.000	0.017	0.016	0.016	0.017	0.016	1.081	1.016	1.000
1971	0.000	0.000	0.000	10.000	0.017	0.016	0.016	0.017	0.016	1.081	1.016	1.000
1972	0.000	0.000	0.000	10.000	0.017	0.016	0.016	0.017	0.016	1.122	1.023	1.000
1973	0.000	0.000	0.000	10.000	0.017	0.016	0.016	0.017	0.016	1.120	1.023	1.000
1974	0.000	0.000	0.000	10.000	0.017	0.016	0.016	0.017	0.016	1.118	1.023	1.000
1975	0.000	0.000	0.000	10.000	0.017	0.016	0.016	0.017	0.016	1.137	1.026	1.000
1976	0.000	0.000	0.000	10.000	0.017	0.016	0.016	0.017	0.016	1.137	1.026	1.000
1977	0.000	0.000	0.000	10.000	0.017	0.016	0.016	0.017	0.016	1.136	1.026	1.000
1978	0.000	0.000	0.000	10.000	0.017	0.016	0.016	0.017	0.016	1.135	1.026	1.000
1979	0.000	0.000	0.000	10.000	0.017	0.016	0.016	0.017	0.016	1.135	1.025	1.000
1980	0.000	0.000	0.000	10.000	0.017	0.016	0.016	0.017	0.016	1.211	1.037	1.000
1981	0.000	0.000	0.640	4.030	0.017	0.016	0.016	0.017	0.016	1.230	1.040	0.965
1982	0.000	0.000	0.628	4.030	0.017	0.016	0.016	0.017	0.016	1.230	1.040	0.963
1983	0.000	0.000	0.628	4.030	0.017	0.016	0.016	0.017	0.016	1.230	1.040	0.943
1984	0.000	0.000	0.639	4.030	0.017	0.016	0.016	0.017	0.016	1.230	1.040	0.936
1985	0.000	0.000	0.644	4.030	0.017	0.016	0.016	0.017	0.016	1.230	1.040	0.929
1986	0.000	0.000	0.641	4.030	0.017	0.016	0.016	0.017	0.016	1.230	1.040	0.900
1987	0.000	0.000	0.612	4.030	0.017	0.016	0.016	0.017	0.016	1.230	1.040	0.890
1988	0.000	0.000	0.570	4.030	0.017	0.016	0.016	0.017	0.016	1.230	1.040	0.876
1989	0.000	0.000	0.557	4.030	0.017	0.016	0.016	0.017	0.016	1.230	1.040	0.856
1990	0.000	0.000	0.535	4.030	0.017	0.016	0.016	0.017	0.016	1.230	1.040	0.825
1991	0.000	0.000	0.514	4.030	0.017	0.016	0.016	0.017	0.016	1.230	1.040	0.825
1992	0.000	0.000	0.519	4.030	0.017	0.016	0.016	0.017	0.016	1.230	1.040	0.825
1993	0.000	0.000	0.498	4.030	0.017	0.016	0.016	0.017	0.016	1.230	1.040	0.825
1994	0.000	0.000	0.500	4.030	0.017	0.016	0.016	0.017	0.016	1.230	1.040	0.825
1995	0.000	0.000	0.332	4.030	0.017	0.016	0.016	0.017	0.016	1.290	1.010	0.825
1996	0.000	0.000	0.332	4.030	0.017	0.016	0.016	0.017	0.016	1.290	1.010	0.825
1997	0.000	0.000	0.332	4.030	0.017	0.016	0.016	0.017	0.016	1.290	1.010	0.825
1998	0.000	0.000	0.332	4.030	0.017	0.016	0.016	0.017	0.016	1.290	1.010	0.825
1999	0.000	0.000	0.332	4.030	0.017	0.016	0.016	0.017	0.016	1.290	1.010	0.825
2000	0.000	0.000	0.332	4.030	0.017	0.016	0.016	0.017	0.016	1.290	1.010	0.825
2001	0.000	0.000	0.117	4.030	0.017	0.016	0.016	0.017	0.016	1.220	1.003	0.825
2002	0.000	0.000	0.117	4.030	0.017	0.016	0.016	0.017	0.016	1.150	0.995	0.825
2003	0.000	0.000	0.117	4.030	0.017	0.016	0.016	0.017	0.016	1.052	0.985	0.825
2004	0.000	0.000	0.117	4.030	0.017	0.016	0.016	0.017	0.016	1.010	0.980	0.825
2005	0.000	0.000	0.117	4.030	0.017	0.016	0.016	0.017	0.016	1.010	0.980	0.825
2006	0.000	0.000	0.117	4.030	0.017	0.016	0.016	0.017	0.016	1.010	0.980	0.825

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 2007   0.000   0.000   0.117   4.030   0.017   0.016   0.016   0.017   0.016   1.010   0.980   0.825
 2008   0.000   0.000   0.117   4.030   0.017   0.016   0.016   0.017   0.016   1.010   0.980   0.825
 2009   0.000   0.000   0.117   4.030   0.017   0.016   0.016   0.017   0.016   1.010   0.980   0.825
 2010   0.000   0.000   0.117   4.030   0.017   0.016   0.016   0.017   0.016   1.010   0.980   0.825
 2011   0.000   0.000   0.117   4.030   0.017   0.016   0.016   0.017   0.016   1.010   0.980   0.825
 2012   0.000   0.000   0.117   4.030   0.017   0.016   0.016   0.017   0.016   1.010   0.980   0.825
 2013   0.000   0.000   0.117   4.030   0.017   0.016   0.016   0.017   0.016   1.010   0.980   0.825
 2014   0.000   0.000   0.117   4.030   0.017   0.016   0.016   0.017   0.016   1.010   0.980   0.825
 2015   0.000   0.000   0.117   4.030   0.017   0.016   0.016   0.017   0.016   1.010   0.980   0.825
 2016   0.000   0.000   0.117   4.030   0.017   0.016   0.016   0.017   0.016   1.010   0.980   0.825
 2017   0.000   0.000   0.117   4.030   0.017   0.016   0.016   0.017   0.016   1.010   0.980   0.825
 2018   0.000   0.000   0.117   4.030   0.017   0.016   0.016   0.017   0.016   1.010   0.980   0.825
 2019   0.000   0.000   0.117   4.030   0.017   0.016   0.016   0.017   0.016   1.010   0.980   0.825
 2020   0.000   0.000   0.117   4.030   0.017   0.016   0.016   0.017   0.016   1.010   0.980   0.825
0
-M170 Warning:
+              Exhaust emissions for gasoline fueled vehicles
               beginning in 1995 have been reduced as a result of
               Gasoline Detergent Additive Regulations (1994).
-M154 Warning:
+              Refueling emissions for LDGV and LDGT after 1998
               model year have been reduced as a result of the
               Onboard Refueling Vapor Recovery Regulations (1994).
0              Emission Factor Modification Profile
+              ____________________________________
0 Eqn. Reg Veh Pol First  Last       Base        DR1        DR2       KINK   Altered
+ ____ ___ ___ ___ _____  ____  _________  _________  _________  _________   _______
    1   1   1   1   1965  1967     7.4880     0.1860                           Yes
    2   1   1   1   1968  1969     4.5760     0.2580                           Yes
    3   1   1   1   1970  1971     3.0990     0.3820                           Yes
    4   1   1   1   1972  1974     3.4910     0.1650                           Yes
    5   1   1   1   1975  1975     1.0680     0.2820                           Yes
    6   1   1   1   1976  1977     1.0710     0.2830                           Yes
    7   1   1   1   1978  1979     1.0740     0.2840                           Yes
    8   1   1   1   1980  1980     0.3710     0.2110                           Yes
    9   1   1   1   1981  1982     0.3980     0.1490     0.2090     1.5300      Yes
   10   1   1   1   1983  1983     0.2580     0.0510     0.1400     2.2200      Yes
   11   1   1   1   1984  1984     0.2570     0.0510     0.1400     2.2200      Yes
   12   1   1   1   1985  1985     0.2510     0.0500     0.1370     2.2200      Yes
   13   1   1   1   1986  1986     0.3030     0.0580                           Yes
   14   1   1   1   1987  1987     0.2990     0.0570                           Yes
   15   1   1   1   1988  1988     0.2900     0.0560                           Yes
   16   1   1   1   1989  1989     0.2880     0.0550                           Yes
   17   1   1   1   1990  1990     0.2000     0.0190     0.0400     2.1300      Yes
   18   1   1   1   1991  1991     0.1980     0.0180     0.0400     2.1300      Yes
   19   1   1   1   1992  1992     0.1970     0.0180     0.0400     2.1300      Yes
   20   1   1   1   1993  1994     0.1950     0.0180     0.0400     2.1300      Yes
   21   1   1   1   1995  2000     0.1690     0.0110     0.0220     8.9000      Yes
   22   1   1   1   2001  2003     0.0940     0.0090     0.0150     7.8700      Yes
   23   1   1   1   2004  2050     0.0940     0.0090     0.0150     7.8700      Yes
```

24	1	2	1	1965	1967	7.4880	0.1860			Yes
25	1	2	1	1968	1969	4.5760	0.2580			Yes
26	1	2	1	1970	1971	3.0990	0.3820			Yes
27	1	2	1	1972	1974	3.4700	0.1760			Yes
28	1	2	1	1975	1975	1.8020	0.2700			Yes
29	1	2	1	1976	1976	1.8130	0.2720			Yes
30	1	2	1	1977	1978	1.8070	0.2710			Yes
31	1	2	1	1979	1980	0.8760	0.2820			Yes
32	1	2	1	1981	1982	1.1400	0.0440	0.1430	1.7300	Yes
33	1	2	1	1983	1983	1.1560	0.0450	0.1450	1.7300	Yes
34	1	2	1	1984	1984	0.4860	0.0220	0.1080	4.4100	Yes
35	1	2	1	1985	1985	0.4830	0.0220	0.1070	4.4100	Yes
36	1	2	1	1986	1986	0.4770	0.0220	0.1060	4.4100	Yes
37	1	2	1	1987	1987	0.4870	0.0220	0.1080	4.4100	Yes
38	1	2	1	1988	1988	0.4860	0.0220	0.1080	4.4100	Yes
39	1	2	1	1989	1989	0.4910	0.0220	0.1090	4.4100	Yes
40	1	2	1	1990	1990	0.3230	0.0180	0.0470	2.1300	Yes
41	1	2	1	1991	1991	0.3060	0.0170	0.0440	2.1300	Yes
42	1	2	1	1992	1993	0.3180	0.0170	0.0460	2.1300	Yes
43	1	2	1	1994	1994	0.3170	0.0170	0.0460	2.1300	Yes
44	1	2	1	1995	2000	0.2140	0.0120	0.0250	9.0600	Yes
45	1	2	1	2001	2003	0.1100	0.0080	0.0160	8.2900	Yes
46	1	2	1	2004	2050	0.1100	0.0080	0.0160	8.2900	Yes
47	1	3	1	1965	1969	9.8850	0.1860			Yes
48	1	3	1	1970	1973	6.4860	0.2580			Yes
49	1	3	1	1974	1978	6.4860	0.1760			Yes
50	1	3	1	1979	1980	0.8870	0.2860			Yes
51	1	3	1	1981	1982	1.1390	0.0440	0.1430	1.7300	Yes
52	1	3	1	1983	1983	1.1590	0.0450	0.1460	1.7300	Yes
53	1	3	1	1984	1984	0.4920	0.0220	0.1090	4.4100	Yes
54	1	3	1	1985	1985	0.5000	0.0230	0.1110	4.4100	Yes
55	1	3	1	1986	1986	0.5090	0.0230	0.1130	4.4100	Yes
56	1	3	1	1987	1987	0.5130	0.0230	0.1140	4.4100	Yes
57	1	3	1	1988	1988	0.5080	0.0230	0.1130	4.4100	Yes
58	1	3	1	1989	1989	0.5080	0.0230	0.1130	4.4100	Yes
59	1	3	1	1990	1990	0.3400	0.0190	0.0490	2.1300	Yes
60	1	3	1	1991	1991	0.3060	0.0170	0.0440	2.1300	Yes
61	1	3	1	1992	1993	0.3180	0.0170	0.0460	2.1300	Yes
62	1	3	1	1994	1995	0.3170	0.0170	0.0460	2.1300	Yes
63	1	3	1	1996	1996	0.3180	0.0170	0.0460	2.1300	Yes
64	1	3	1	1997	2000	0.2600	0.0120	0.0300	9.2500	Yes
65	1	3	1	2001	2003	0.2580	0.0120	0.0300	9.2500	Yes
66	1	3	1	2004	2050	0.2580	0.0120	0.0300	9.2500	Yes
67	1	4	1	1994	1994	0.5215	0.0329			Yes
68	1	4	1	1995	1995	0.5210	0.0329			Yes
69	1	4	1	1996	1996	0.5224	0.0328			Yes
70	1	4	1	1997	1997	0.5219	0.0328			Yes
71	1	4	1	1998	1998	0.5213	0.0327			Yes
72	1	4	1	1999	1999	0.5213	0.0327			Yes
73	1	4	1	2000	2000	0.5248	0.0327			Yes

74	1	4	1	2001	2001	0.5248	0.0327			Yes
75	1	4	1	2002	2002	0.5248	0.0327			Yes
76	1	4	1	2003	2003	0.5248	0.0327			Yes
77	1	4	1	2004	2050	0.4009	0.0257			Yes
78	1	5	1	1995	1995	0.1610	0.0110	0.0210	8.9000	Yes
79	1	5	1	1996	1996	0.1610	0.0110	0.0210	8.9000	Yes
80	1	5	1	1997	1997	0.1610	0.0110	0.0210	8.9000	Yes
81	1	5	1	1998	1998	0.1610	0.0110	0.0210	8.9000	Yes
82	1	5	1	1999	1999	0.1610	0.0110	0.0210	8.9000	Yes
83	1	5	1	2000	2000	0.1610	0.0110	0.0210	8.9000	Yes
84	1	5	1	2001	2001	0.0660	0.0060	0.0110	7.8700	Yes
85	1	5	1	2002	2002	0.0660	0.0060	0.0110	7.8700	Yes
86	1	5	1	2003	2003	0.0660	0.0060	0.0110	7.8700	Yes
87	1	5	1	2004	2050	0.0660	0.0060	0.0110	7.8700	Yes
88	1	6	1	1995	1995	0.2710	0.0150	0.0380	3.8700	Yes
89	1	6	1	1996	1996	0.2710	0.0150	0.0380	3.8700	Yes
90	1	6	1	1997	1997	0.2310	0.0110	0.0270	9.2100	Yes
91	1	6	1	1998	1998	0.2310	0.0110	0.0270	9.2100	Yes
92	1	6	1	1999	1999	0.2310	0.0110	0.0270	9.2100	Yes
93	1	6	1	2000	2000	0.2310	0.0110	0.0270	9.2100	Yes
94	1	6	1	2001	2001	0.2020	0.0100	0.0240	9.0100	Yes
95	1	6	1	2002	2002	0.2020	0.0100	0.0240	9.0100	Yes
96	1	6	1	2003	2003	0.2020	0.0100	0.0240	9.0100	Yes
97	1	6	1	2004	2050	0.2020	0.0100	0.0240	9.0100	Yes
98	1	7	1	1994	2003	0.6516	0.0000			Yes
99	1	7	1	2004	2050	0.5904	0.0000			Yes

```
0I/M program #1 selected:

0Start year (Jan 1):  1978
 Pre-1981 stringency: 31%
 First MYR covered:   1967
 Last MYR covered:    1980
 Waiver (pre-1981):    8.%
 Waiver (1981+):       8.%
 Compliance Rate:     96.%
 Inspection type:
 Test Only
 Inspection frequency: Annual
 I/M program #1 vehicle types
      LDGV - Yes
     LDGT1 - Yes
     LDGT2 - Yes
      HDGV - Yes
 1981 & later MYR test type:
      Idle
 Cutpoints, HC:   220.000
 Cutpoints, CO:     1.200
 Cutpoints, NOx:  999.000
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I/M program #2 selected:

Start year (Jan 1):  1978
Pre-1981 stringency: 31%
First MYR covered:   1981
Last MYR covered:    1994
Waiver (pre-1981):    8.%
Waiver (1981+):       8.%
Compliance Rate:     96.%
Inspection type:
Test Only
Inspection frequency: Annual
I/M program #2 vehicle types
     LDGV - Yes
    LDGT1 - Yes
    LDGT2 - Yes
     HDGV - Yes
1981 & later MYR test type:
     Idle
Cutpoints, HC:   220.000
Cutpoints, CO:     1.200
Cutpoints, NOx:  999.000
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Low alt, Annl and Bien Insp Freq TECH 1 & 2 I/M cred data

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     Annual Idle Only 220/1.2 Cutpoints IDLE.IMC
0Functional Check Program Description:
0Check Start Model Yrs Vehicle Classes Covered    Inspection        Comp   Eff
      (Jan1) Covered   LDGV LDGT1 LDGT2 HDGV   Type        Freq     Rate   Adj
 ATP   1988  1967-2050 Yes  Yes   Yes   Yes Test Only     Annual    96.0%  1.00
0Air pump system disablements:      Yes  Catalyst removals:                 Yes
 Fuel inlet restrictor disablements: Yes  Tailpipe lead deposit test:        Yes
 EGR disablement:                    No   Evaporative system disablements:    No
 PCV system disablements:            No   Missing gas caps:                   No
0TOG HC emission factors include evaporative HC emission factors.
0_____________________________________________________________________________________________________________
0Emission factors are as of July 1st of the indicated calendar year.
0User supplied  basic exhaust emissions rates, veh registration distributions.
0Cal. Year: 1990        I/M Program: Yes       Ambient Temp: 82.2 (F)           Region: Low
                  Anti-tam. Program: Yes     Operating Mode: 20.6 / 27.3 / 20.6   Altitude:  500. Ft.
                   Reformulated Gas: Yes         ASTM Class: B
0PX90SB.INP Spr                                Minimum Temp:  64. (F)         Maximum Temp:  88. (F)
                      Period 1 RVP:  8.1      Period 2 RVP:  8.1        Period 2 Start Yr: 2020
0  Veh. Type:      LDGV     LDGT1     LDGT2      LDGT      HDGV      LDDV      LDDT      HDDV      MC     All Veh
+                 ______    ______    ______    ______    ______    ______    ______    ______    ______    ______
 Veh. Speeds:     19.6      19.6      19.6                19.6      19.6      19.6      19.6      19.6
    VMT Mix:      0.645     0.168     0.082               0.031     0.008     0.002     0.056     0.008
0Composite Toxic Emission Factors (mg/Mile)
  = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = =
 Total    Bnz    121.98    117.29    201.73    144.92    404.32     14.81     20.95     32.59    164.88   130.724
 Exhst    Bnz    103.71     98.16    169.96    121.66    325.13     14.81     20.95     32.59    119.07   110.310
 Evap.    Bnz      7.44      8.91     17.02     11.57     53.81                                   40.09     9.668
 Refuel   Bnz      2.74      3.53      3.75      3.60      6.14                                             2.859
 Runing   Bnz      6.81      5.57      9.90      6.99     17.28                                             6.679
 Rsting   Bnz      1.28      1.13      1.09      1.11      1.95                                    5.72     1.208
  = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = =
 Exhst    Act      8.63      9.08     18.56     12.18     46.14      9.11     12.89     89.39     15.21    15.244
  = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = =
 Exhst    Frm     26.73     30.13     65.27     41.63    237.28     28.58     40.44    242.72     56.76    49.290
  = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = =
 Exhst    But     10.70     10.60     24.59     15.18     50.54      6.66      9.43     18.93     23.31    13.576
  = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = =
 Total    MTB      0.00      0.00      0.00     30.79      0.00      0.00      0.00      0.00      0.00     0.000
 Exhst    MTB      0.00      0.00      0.00      5.71      0.00      0.00      0.00      0.00      0.00     0.000
 Evap.    MTB      0.00      0.00      0.00     15.57      0.00                                    0.00     0.000
 Refuel   MTB      0.00      0.00      0.00      3.13      0.00                                             0.000
 Runing   MTB      0.00      0.00      0.00      5.50      0.00                                             0.000
 Rsting   MTB      0.00      0.00      0.00      0.87      0.00                                    0.00     0.000
 _____________________________________________________________________________________________________________
-M170 Warning:
+             Exhaust emissions for gasoline fueled vehicles
              beginning in 1995 have been reduced as a result of
              Gasoline Detergent Additive Regulations (1994).
-M154 Warning:
+             Refueling emissions for LDGV and LDGT after 1998
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               model year have been reduced as a result of the
               Onboard Refueling Vapor Recovery Regulations (1994).
0Emission factors are as of July 1st of the indicated calendar year.
0User supplied  basic exhaust emissions rates, veh registration distributions.
0Cal. Year: 1990        I/M Program: Yes       Ambient Temp:100.4 (F)           Region: Low
                  Anti-tam. Program: Yes     Operating Mode: 20.6 / 27.3 / 20.6   Altitude:  500. Ft.
                   Reformulated Gas: Yes         ASTM Class: B
0PX90SB.INP Sum                                Minimum Temp:  83. (F)        Maximum Temp: 105. (F)
                       Period 1 RVP:  8.1      Period 2 RVP:  8.1        Period 2 Start Yr: 2020
0  Veh. Type:      LDGV     LDGT1     LDGT2      LDGT      HDGV      LDDV      LDDT      HDDV       MC     All Veh
+                 ______    ______    ______    ______    ______    ______    ______    ______    ______    ______
 Veh. Speeds:     19.6      19.6      19.6                19.6      19.6      19.6      19.6      19.6
     VMT Mix:      0.645     0.168     0.082               0.031     0.008     0.002     0.056     0.008
0Composite Toxic Emission Factors (mg/Mile)
  = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = =
 Total    Bnz    157.97    149.56    242.01    179.81    506.40     14.81     20.95     32.59    203.70   166.133
 Exhst    Bnz    122.31    114.93    186.14    138.23    364.56     14.81     20.95     32.59    118.40   127.676
 Evap.    Bnz     12.46     13.98     23.66     17.15     85.74                                   75.88    15.572
 Refuel   Bnz      3.60      4.64      4.93      4.73      8.07                                              3.757
 Runing   Bnz     17.49     14.15     25.48     17.86     44.80                                             17.135
 Rsting   Bnz      2.11      1.86      1.80      1.84      3.22                                    9.43     1.993
  = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = =
 Exhst    Act     10.30     10.69     20.03     13.75     51.68      9.11     12.89     89.39     15.12    16.883
  = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = =
 Exhst    Frm     31.99     35.44     69.88     46.71    265.81     28.58     40.44    242.72     56.44    54.840
  = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = =
 Exhst    But     12.57     12.36     25.92     16.80     56.62      6.66      9.43     18.93     23.18    15.370
  = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = = =
 Total    MTB      0.00      0.00      0.00     30.79      0.00      0.00      0.00      0.00      0.00     0.000
 Exhst    MTB      0.00      0.00      0.00      5.71      0.00      0.00      0.00      0.00      0.00     0.000
 Evap.    MTB      0.00      0.00      0.00     15.57      0.00                                    0.00     0.000
 Refuel   MTB      0.00      0.00      0.00      3.13      0.00                                              0.000
 Runing   MTB      0.00      0.00      0.00      5.50      0.00                                              0.000
 Rsting   MTB      0.00      0.00      0.00      0.87      0.00                                    0.00     0.000
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