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Technical Report

Guidance on Estimating Motor Vehicle Emission Reductions From the Use of Alternative Fuels and Fuel Blends

January 29, 1988

Emission Control Technology Division
Office of Mobile Sources
Office of Air and Radiation
U. S. Environmental Protection Agency
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1.0 INTRODUCTION

1.1 Purpose

This document provides methods and assumptions for estimating the impact of use of alternative fuels and fuel blends on motor vehicle emissions including HC, CO, and NOx*. The information is presented in a format which assumes it will be used by State and local air quality planning agencies in preparing current and future emissions inventories and emission reduction strategies during 1988, 1989, and 1990. Such planning efforts will be necessary in areas which receive calls from EPA for revisions to their ozone** or CO State Implementation Plans (SIP) following their failure to attain (or in a few cases following their failure to provide for attainment in a prospective sense) the National Ambient Air Quality Standards (NAAQS) for these pollutants. EPA has recently proposed requirements applicable to these SIP calls (52 FR 45044, November 24, 1987), and many affected areas will need to estimate current and future year motor vehicle emissions. Use of alternative fuels and fuel blends is likely to be part of future scenarios that will be examined in many areas.

Adherence to the methods and assumptions in this document when preparing SIP revisions will facilitate EPA review and avoid the need for States to justify those aspects of their analysis. Differing assumptions and methods, if used, will be subject to closer and more questioning EPA review. In all cases, final EPA approval or disapproval of a particular State's SIP revision occurs only after notice and opportunity for public comment, including any comments on the methods and assumptions recommended here.

While not specifically addressed, the information in this document may be useful for estimating the emissions impact of smaller scale use of alternative fuels than might be contemplated in a SIP revision.

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* Some studies have suggested that particulate emissions may also be affected with alternative fuels; when sufficient data are available in this area, EPA may want to include provisions for the effect of alternative fuels on particulate emissions.

** Areas receiving ozone SIP calls and considering adoption of an alternative fuels program should account for its impact on both hydrocarbon and CO emission inventories, since both are inputs to the latest model for predicting future ozone attainment. Directionally, CO emission reductions from alternative fuels will assist in attaining the ozone NAAQS, but the strength of this effect has not yet been documented for the range of local conditions which affect ozone formation.

The reader is warned that the methods described in this document have not been cast into the form of a self-contained computer model or single look-up table. At the present time, hand calculation and transcription of intermediate results is necessary. The resourceful planner may be able to automate these steps, however.

This document is not intended to be an all-inclusive manual on alternative fuel implementation issues. For instance, it does not address pump labeling, consumer education, incentives such as state tax exemptions, or specific methods to monitor and track actual fuel usage trends.

1.2 Alternative Fuels Addressed

Separate information is provided for the following fuels or types of fuels. In some cases cross references are made between fuels to avoid repetition of numerical information that can apply to more than one fuel.

- o 10% ethanol blends (gasohol).
- o Methanol blends (including DuPont and Oxinol).
- o Methyl Tertiary Butyl Ether (MTBE) blends.
- o Retrofit of gasoline vehicles to achieve dual-fuel gasoline/compressed natural gas (CNG) capability and new CNG vehicles.
- o Newly manufactured vehicles designed for operation on methanol fuel, such as 85% methanol / 15% gasoline or 100% methanol. These vehicles can be designed with different emission levels. The emission reduction credit given is a function of the actual emission levels of the vehicles as discussed later.

1.3 Usage Scenarios Addressed; Tracking

This document addresses only the issue of individual vehicle effects when operating on an alternative fuel. A government program on alternative fuels could take a variety of forms with respect to requiring or encouraging the use of alternative fuels. A regulatory mandate to require certain vehicles to use one specific fuel is one approach. The following are some of the other forms a government program might take:

- o A requirement that all fuel sold for use in gasoline vehicles have a minimum oxygen content. (Up to a certain point, increasing oxygen content results in proportional reductions in tailpipe CO emissions.)

Depending on the nature of the oxygen content requirement, ethanol blends (gasohol), methanol blends, and MTBE blends might all compete and achieve a market share mix that depends on relative cost and local consumer attitudes and other conditions. There are basically two approaches. First, require a minimum oxygen content for all fuel, without allowing any trading. Presently, any such minimum oxygen content requirements that exceeds 2% would preclude marketing of MTBE blends in unleaded fuel, since 2% oxygen is the limit of EPA's "substantially similar" regulation. Under this approach, environmental regulators must be able to predict with reasonable confidence the future market share mix in order to calculate the net effect on emissions since each of these three blends affects emissions differently. If any gasohol is sold, the average oxygen content will exceed the program's minimum requirement, for example.

A second approach would set a minimum average oxygen level, but allow fuel suppliers to purchase and sell "oxygen credits." This would permit states to set a much higher average oxygen content requirement* than under the first approach, since the market for oxygen credits eventually will automatically adjust the mix to achieve the targeted level of emission reductions yet still permit different blends (and straight gasoline) to share in the market mix. (Achieving a 2.5% oxygen average in a program which only sets a minimum requirement of 2% would require that 30% of consumers voluntarily select gasohol over MTBE. Such a large market share now exists in a few markets with sizable state tax exemptions.) Fuel blenders could satisfy the 2.5% average oxygen requirement by a combination of MTBE and by purchasing oxygen credits to make up the difference between MTBE's 2% oxygen content and the 2.5% requirement. Those credits would be supplied by alcohol fuel blenders, whose 3.7% oxygen content earns a surplus against the 2.5% standard. Using this example, any number of market mixes would achieve the 2.5% average oxygen content requirement: for example, MTBE 45%, gasohol 45% and straight gasoline (oxygen free) 10%. Even a 3% oxygen content standard could be achieved by a market mix of MTBE 18%, gasohol 72%, and straight gasoline 10%.

*Some areas may find it necessary (or desirable) to set higher oxygen content requirements in order to meet the CO reduction targets to be established in EPA's non-attainment strategy for CO and ozone. Alternative CO reduction measures may be much more costly or non-existent. For instance, a state could require a 2.5% minimum average oxygen level.

The second approach is superior to the first from several perspectives. It allows states to achieve a greater level of CO reduction, while preserving the possibility of consumer choice between MTBE and alcohol blends. At a very high average oxygen content requirement the possible market shares for straight gasoline and MTBE blends might be so small that some fuel distributors and retailers choose not to carry them due to the disproportionate handling and overhead costs, if consumers' willingness to pay is not commensurate. It internalizes the relative environmental costs and benefits of the various fuels via the payments by straight gasoline refiners and by MTBE blenders to alcohol blenders. This results in a closer correspondence between what vehicle owners pay to drive and the environmental and public health damage caused by their driving. It also provides greater environmental certainty and eliminates the need for regulators to predict the market share mix, since the market will result in a mix which achieves the necessary emission reductions. States could design their own oxygen trading system using EPA's lead trading rules as a model, or they could propose a better system subject to EPA's approval of it as adequate to enforce the oxygen level on which emission reduction estimates are based.

It should be noted that the averaging approach has some of the advantages mentioned here even when applied at oxygen levels of 2% or less, for example it would allow some sales of straight gasoline. Planners must also be alert to the possibility that older, higher emitting vehicles may use the lower oxygen content fuels disproportionately more than others. If so, the average oxygen content may vary by model year, affecting the overall emission reductions adversely.

- A requirement that certain types of fleets retrofit all newly purchased vehicles to operate on compressed natural gas.

- An initially voluntary but by agreement irrevocable and enforceable commitment by a large fleet to use an alternative fuel. This might be part of an emissions trade, offset, or netting agreement, for example.

- o An incentive program for use of one fuel or a group of fuels based on differences in State or local fuel taxes or vehicle sales taxes.

- o A promotional program based solely on voluntary participation.

Predicting how many and which types of vehicles will use each type of fuel in response to a specific planned government program is an important step in estimating its effect on motor vehicle fleet emissions. This document does not attempt to provide standard assumptions on usage of alternative fuels. Instead, States must demonstrate a reasonable basis for their own estimates of fuel use by type. EPA technical staff are available to discuss such estimates before States invest heavily in analysis or planning based on them. Purely promotional programs may be difficult to assess prior to actual start up.

EPA's policy on post-1987 nonattainment requires affected areas to both adopt emission reduction measures <u>and</u> to report periodically to EPA on the status of their implementation efforts and on the year-to-year changes in their emission inventory. If this inventory tracking system shows significant differences between the expected inventory trend and the trend that actually occurs, EPA will require corrective or offsetting action by the area as a condition for avoiding federal funding and/or new source permitting restrictions. States which adopt an alternative fuels program, and receive EPA approval for emission reduction estimates based on predicted future usage levels as a result of that program, will be required to track and report on actual usage levels. Significant errors in prediction may require further revision of the SIP.

A final usage issue relates to seasonal requirements or incentives for alternative fuels and how to predict usage in the off season when use is not required or subsidized. For example, an area might require all gasoline-type fuels to contain a certain minimum level of oxygen only in winter months, but this may indirectly result in substantially higher use of oxygenated blends in summer months. Depending on a number of factors, summer time VOC emissions may be increased or decreased as a result. Areas adopting winter time alternative fuels programs should explicitly predict their effect, if any, on summer time VOC and hence on VOC reduction targets. This document can be used to estimate summer VOC effects, but only given an external prediction of fuel use by type. Each State must demonstrate a reasonable expectation that its prediction is accurate. EPA may require actual use in summer to be tracked and reported.

1.4 Organization

This document is organized as follows.

Section 2.0 provides some background on how motor vehicle emission inventories are estimated apart from the complications posed by alternative fuels.

Section 3.0 presents the core technical assumptions about the effect of each alternative fuel on various types of vehicles. These assumptions are for the most part not fully derived or defended in this document, but appropriate references to other documents are provided.

Section 4.0 explains how these core assumptions can be used to adjust the output of MOBILE3 or MOBILE4* to reflect an alternative fuel usage scenario of interest.

Section 5.0 gives instructions on how to obtain and use a special version of MOBILE3's or MOBILE4's Fortran code so as to achieve in practice the steps described in principle in Section 4.0.

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* MOBILE3 is a computer model designed to predict fleet average emissions by calendar year given various inputs that describe the local fleet make-up and operating conditions. MOBILE4 will be an updated version of this model and is expected to be released shortly after this document.

2.0 BACKGROUND ON SIP INVENTORIES FOR MOTOR VEHICLE EMISSIONS

Except for California areas, EPA requires the motor vehicle emission inventories in all ozone, CO, and NO_2 SIP revisions to be based on the most recent available version of EPA's mobile source emission factor computer model. The current version is MOBILE3; MOBILE4 is under development and expected to be released early in 1988, for use in preparing the SIP revision for which EPA will call in early 1988. MOBILE4 will be updated internally with new information, and will also allow planners to account for the influence of some factors not addressed by MOBILE3. Externally, MOBILE4 will resemble MOBILE3 and will be used in the same manner by planners. The discussion that follows will refer mostly to MOBILE3, but will apply to MOBILE4 also.

The function of MOBILE3 is to provide estimates of the average emission levels of in-use motor vehicles, expressed in grams per mile. The normal output provides average levels for each of HC (either total or non-methane at the user's direction), CO, and NOx for each vehicle type and for all vehicle types averaged together. The following vehicle types are used.:

- o light-duty gasoline vehicles (LDGV)
- o light-duty gasoline trucks below 6000 GVWR (LDGT1)
- o light-duty gasoline trucks between 6000 and 8500 GVWR (LDGT2)
- o light-duty diesel vehicles (LDDV)
- o light-duty diesel trucks below 8500 GVWR (LDDT)
- o heavy-duty gasoline vehicles (HDGV)
- o heavy-duty diesel vehicles (HDDV)
- o motorcycles (MC)

A planner typically wishes to estimate motor vehicle emissions of a given pollutant for a certain city, an individual roadway, or a collection of similar roadway segments for a year, a day, or an hour. He or she would do this by making or obtaining an estimate of the number of vehicle miles traveled (VMT) in the geographic area and time period of interest and multiplying it by the gram per mile "emission factor" produced by MOBILE3.

To allow the planner to get an "emission factor" that is representative of the geographic area and time period under investigation, MOBILE3 allows the user to specify a number of input parameters to reflect local conditions. The more important of these factors are the following:

- o whether the area is at low or high altitude
- o the VMT split by vehicle type
- o for each vehicle type, the age mix of vehicle registrations
- o for each vehicle type, the mileage accumulation rate by age of vehicle
- o ambient temperature
- o average speed of the traffic in the area
- o the mix of cold versus warmed up vehicles
- o the features of any periodic vehicle inspection program operating in the area of interest
- o local tampering and misfueling rates
- o the calendar year of interest

The last item is very important since it determines the mix of vehicles designed to different emission standards and their age, and therefore deterioration.

For every input parameter except calendar year, MOBILE3 (or its user's manual) provides a default value for users not wishing or able to use local conditions. The defaults generally represent summer time nationwide urban conditions.

The influence of some input parameters is very strong, and the overall emission factor output can vary by a factor of 3 or 4 or more by setting some inputs to extreme but still realistic values. Speed, temperature, and cold/warm mix are particularly influential. These inputs can affect the relative contribution of different vehicle types and vintage to the overall emission factor outputs, as well as its absolute level.

The default inputs to MOBILE3 are also the conditions of the official Federal Test Procedure (FTP) for vehicle emissions, which is used for regulatory purposes. The FTP conditions are also used in nearly all research projects involving vehicle emissions and factors that affect them. In particular, virtually all reliable data on the emissions effects of alternative fuels has been collected under these FTP conditions. An important issue in assessing the impact of alternative fuels for SIP purposes is to provide a way to bridge between test data collected under "default" FTP conditions and the "local" conditions facing individual SIP planners. This issue is addressed by the method presented in subsequent sections. Basically, the bridging assumption is that a percentage change observed during testing under FTP conditions can be applied to emissions under non-FTP local conditions, even if the base emission levels on ordinary fuel are quite different under the two sets of conditions.

This document does not address how local inputs for MOBILE3 should be estimated, or methods for estimating VMT in a particular area and time period. EPA Regional Offices should be contacted for guidance in these areas.

3.0 PER-VEHICLE EMISSION REDUCTIONS WITH ALTERNATIVE FUELS

3.1 Oxygenated Gasoline Blends

3.1.1 10% Ethanol Blends (3.7% Oxygen)

Much of the information in Section 3 is summarized from recent EPA reports on the effects of fuel volatility on vehicle emissions.[1,2] Much of the information also comes from analyses and test programs run by the Colorado Department of Health for exhaust emissions of vehicles at high altitude [3,4,5,6,7] and from statistical analyses of low altitude data performed by the EPA Office of Mobile Sources.[8,9,10,11,12,13] Much of the information in this section for ethanol blends is applicable to methanol blends and, to a lesser extent, MTBE blends both of which are discussed in later Sections (3.1.2 and 3.1.3).

3.1.1.1 Exhaust HC, CO and NOx Emissions

The use of an oxygenated fuel blend such as gasoline with 10% ethanol (gasohol) results in an enleanment (i.e., more oxygen for fuel combustion) due to the oxygen contained in the blend itself. Fuel metering devices on vehicles such as carburetors or fuel injectors (without an oxygen sensor or with an oxygen sensor but operating in the "open loop" mode where the sensor is not functional) usually meter fuel and air volumetrically. Thus, the oxygen in the fuel results in less fuel and more total oxygen reaching the engine for fuel combustion since the amount of air is not diminished. If the initial mixture when using gasoline is rich of stoichiometric, this enleanment results in reduced exhaust HC and CO but causes an increase in vehicle nitrogen oxide (NOx) emissions.

A closed-loop vehicle with an operating oxygen sensor in control of the engine will try to compensate for the oxygen present in the fuel by increasing the fuel flow until stoichiometry is achieved. If its fuel system has the necessary range of control authority, such a vehicle experiences little or no enleanment due to the blend for those portions of vehicle operation when the oxygen sensor is functioning and in control of the engine. Thus, one expects a smaller absolute reduction in exhaust HC and CO emissions from vehicles with oxygen sensors (generally 1981 and later model years) than earlier model year vehicles and perhaps a smaller proportional (percentage) reduction as well. It should be noted, however, that a closed-loop vehicle produces most of its CO during its occasional open-loop modes of operation.

HC and CO emissions are generally greater for vehicles at high altitude since a given volume of air at high altitude has lower density and less oxygen. Open-loop vehicles operate richer more often and to a greater degree than they would at low altitude which results in greater grams per mile emissions. The same holds for closed-loop vehicles during their open-loop modes unless there is some compensation for altitude in open-loop modes. One issue EPA has had to address is how these differences in operation between altitudes affects the reductions -- both absolute and relative -- that will occur with use of oxygenated blends.

Various organizations have done extensive tests under low altitude conditions on oxygenated blends providing a large but somewhat disjointed data base that can be used to quantify the effects of these blends on emissions. Only the Colorado Department of Health has conducted and published data from exhaust emission tests on numerous vehicles at high altitude.

EPA has reviewed the available data and performed several statistical analyses to better quantify these emission effects. A companion report[25] to this document will provide more details on these analyses. An analysis of emission tests of a group of vehicles tested with ethanol and methanol gasoline blends shows similar results for both fuels when the results are adjusted for RVP differences using the extensive emission data base obtained by EPA. This suggests that the most important factor is fuel oxygen content rather than the type of alcohol. Accordingly, EPA has pooled exhaust emission data from different types of oxygenated blends, using percent oxygen content and RVP as the only important variables influencing exhaust emission reductions.

Table 3-1 lists EPA's conclusions on the exhaust emission changes with oxygenated blends for fuels with 3.7% oxygen (gasohol or methanol blends) and 2% oxygen (an 11% MTBE blend). Analysis of the separate low and high altitude data bases indicates essentially the same effects of blends on a percent basis, as shown in the table. HC and CO reductions on an absolute basis are generally higher at high altitude. Both CO and exhaust volatile organic compounds (VOC) decrease while NOx increases. VOC, in effect, are the non-methane hydrocarbons with adjustments made to account for the mix of true hydrocarbons, alcohols, and aldehydes that is expected with each blend. Because vehicle exhaust emissions with oxygenated fuels are still primarily true hydrocarbons, the adjustment is small. Specifically, EPA assumes that the effects of slightly increased alcohol and aldehyde emissions balance each other.

One important point to note is that some, but not all, newer closed-loop vehicles are equipped with "adaptive learning." Properly functioning vehicles with adaptive learning continuously adjust their open-loop fuel calibrations based on the most recent period of closed-loop operation. Thus, they can in theory compensate at least partially for fuel-caused enleanment even when the oxygen sensor is not in control, such as during cold starts and heavy accelerations. They may also not run as rich in failure modes as simpler closed-loop vehicles. These vehicles have been expected by some to have lower exhaust CO (and HC) reductions from oxygenated blends than earlier closed-loop vehicles. These lower reductions expected for the adaptive learning vehicles are not reflected in the test data available. Thus, for the purposes of this report, the same emission reduction is applied to all closed-loop vehicles regardless of model year. The emission reduction is based on the available emission data.

Also, increases in RVP from ASTM type levels (e.g., 11.5 psi in a moderate summer condition), as can occur with ethanol blends that have not been adjusted to meet ASTM volatility specifications, cause an increase in exhaust emissions. For example, an increase in RVP of 1 psi results in carbon monoxide increases of about 3.1% for pre-1981 vehicles and about 7.6% for 1981 and newer vehicles for 75° ambient temperatures. Also, a 1 psi RVP increase results in exhaust hydrocarbon increases of about 1.8% from pre-1981 vehicles and 3.7% from 1981 and newer vehicles for 75° ambient temperatures. For temperatures of 50° or below, RVP correction factors are currently assumed to be zero. For temperatures between 50° and 75°, the percentage factor should be linearly interpolated. The adjustments for 75° are reflected in the "+0.76 psi" columns of Table 3-1 which give the emission changes with a higher RVP ethanol blends; these numbers reflect an average increase in volatility for ethanol blends of 0.76 psi. It should be noted that EPA will continue to review emission data at different temperatures and RVP and will develop updated factors as needed.

3.1.1.2 Evaporative HC Emissions

Evaporative emissions consist of hot soak and diurnal emissions. Hot soak emissions occur during the period immediately following engine shut-down (i.e., at the end of each vehicle trip). These losses will originate from both the fuel metering system and from the fuel tank. These emissions are greater for carbureted vehicles than for vehicles with fuel injection. Diurnal emissions consist of hydrocarbons both evaporated and displaced from the vehicle's fuel tank as the vehicle tracks the diurnal swing in ambient temperatures. Each day, as the fuel in the tank and the vapor above the fuel heat up, more of the liquid fuel evaporates and the vapor itself expands, with both phenomena causing hydrocarbons to be released into the atmosphere.

MOBILE3 outputs a single evaporative emission rate in grams per mile by assuming that each vehicle makes 3.05 daily trips totalling 31.1 miles per day, so that there are 3.05 incidences of hot soak emissions for every diurnal emission.

However, in reality, the relative number of hot soak and diurnal emissions vary with vehicle age since older vehicles are used for fewer daily trips (and also fewer miles but not in exact proportion) than newer vehicles. MOBILE4 will account for these differences. Also, local areas may in MOBILE4 be able to specify local factors. To account for this accurately in assessing alternative fuels (which affect hot soak and diurnal emissions differently) would be very difficult with MOBILE3 and perhaps also in MOBILE4, and is beyond this document. This document uses the fixed weighting from MOBILE3 for all age vehicles.

Fuel volatility varies by season and from one part of the country to another. For example, in most areas of the country, the recommended ASTM RVP level during the summer months is generally 11.5 psi, although some areas have lower ASTM RVP limits but higher temperatures and/or higher altitude. MOBILE4 will explicitly account for any combination of fuel RVP and ambient temperatures in calculating emissions on non-oxygenated fuel. This report gives data on evaporative emissions with both low and high volatility fuel, of 9 and 11.5 psi RVP respectively. The correct case to use should be selected carefully. For the purposes of this report, the percent reduction values given under the 11.5 psi RVP headings should be used whenever local RVP is about equal to the local ASTM limit, i.e., nearly everywhere at present. The 9.0 psi RVP values are provided because EPA has proposed a new limit of 9.0 psi that will apply in areas now having an 11.5 psi ASTM limit for some years for which state and local planners will wish to estimate blend effects. These two cases are evaluated separately because evaporative emissions are a non-linear function of RVP. Thus, the percentage reduction effects of oxygenated fuels at one RVP level could not be easily evaluated based on the effects at the other level.

Test data indicate that evaporative emissions from an ethanol blend consist mostly of gasoline vapor with a small amount of ethanol, roughly 15% ethanol. It is important to note that gasohol of equal RVP to the gasoline it displaces is assumed to result in equal moles of diurnal emissions; the lower molecular weight of ethanol (46) versus the typical evaporative hydrocarbon (64) results in slightly lower mass emissions. This factor has been accounted for in the tables.

If no adjustments are made to compensate for it, use of alcohol increases RVP compared to the base gasoline. Since a blend of 10% ethyl alcohol (ethanol) in gasoline presently is not subject to ASTM or any federal RVP limits, the final blend will be about 0.76 psi higher in RVP and can exceed ASTM levels. However, state or local governments might enforce ASTM limits for gasohol and EPA may establish the same RVP limit for gasohol as for gasoline when it finalizes the RVP reduction proposal mentioned above. The tables contain separate columns to reflect both cases.

Addition of ethanol to gasoline also changes the distillation curve of the fuel and, in particular, increases the percent evaporated at 160°F. The increase in the 160° point has been shown to result in an increase in hot soak evaporative emissions even if the RVP of the gasohol is kept at the same level as the displaced gasoline.[12]

Another important phenomenon to consider with ethanol blends is "commingling" which refers to the mixing of gasoline/alcohol blends with non-oxygenated gasolines in vehicle fuel tanks whenever consumers switch from one fuel type to the other when refueling their vehicles at different service stations. The resultant commingled blend consisting of a mixture of gasohol and gasoline will have a higher RVP level than the simple volume weighted average of the gasohol and gasoline. With 50% market penetration of gasohol and 50% gasoline, a maximum amount of commingling of the two different fuel types will occur. Table 3-2 gives these values for ethanol blends.[30] If the market penetration of an ethanol blend is other than 50%, a commingling value should be determined by use of a quadratic equation through the three points given for 0%, 50%, and 100% market share (see Appendix A). Very limited data indicate that there may be no commingling effect when ethanol blends and MTBE blends or methanol blends are mixed; therefore, this document assumes no commingling effect for MTBE blends.[27,28] This also means that Table 3-2 cannot be used for commingling when MTBE and ethanol blends are both sold along with base gasoline; see Appendix B for more details.

A final factor has been raised for ethanol blends concerning the relative contribution of ethanol emissions to ozone formation compared to hydrocarbons in either exhaust or evaporative emissions. Some smog chamber data have indicated that on a mass basis ethanol may be less reactive than the typical hydrocarbon compounds in exhaust and evaporative emissions.[22] This lower reactivity in effect has been incorporated into the evaporative VOC adjustment factors by ignoring the mass of oxygen in the ethanol. The issue of relative reactivity of ethanol on a per-carbon atom basis is much less clear-cut and no further adjustment has been used in this report. The available data indicate that at low HC/NOx ratios there may be some reactivity benefit, but at higher HC/NOx ratios this may not be true.[31]

3.1.2 Methanol Blends with 3.7% Oxygen

To date, two different waivers for methanol blends have been approved. The first is the ARCO Oxinol waiver for up to 4.75% methanol and 4.75% t-butanol as a cosolvent alcohol. This mixture has an oxygen content of 3.5%. Variations in the amount of the two alcohols are permitted as long as the methanol to cosolvent ratio is not over one to one (i.e., more methanol than cosolvent) and the total oxygen content does not exceed 3.5%. The second waiver is the DuPont waiver for a maximum of 5% methanol and a minimum of 2.5% cosolvent alcohol with a maximum total oxygen content of 3.7%. The cosolvent alcohols can be ethanol, propanols, or butanols. Use of 5% methanol and 2.5% ethanol results in an oxygen level of 3.7%. Use of propanols or butanols for cosolvents would result in lower oxygen levels if only 2.5% cosolvent alcohol were used.

3.1.2.1 Exhaust HC, CO and NOx Emissions

As mentioned before, the exhaust emission effect depends only on the fuel oxygen level and RVP. Therefore, Table 3-1 also applies to methanol blends. If it is anticipated that fuels will be blended under waivers such as the DuPont or ARCO waivers that do not specify a lower limit on oxygen content, the program should take into account the possibility that blending could be done at less than the maximum oxygen level allowed by the EPA waiver. If the expected average oxygen level is less than 3.7%, the reduction in exhaust HC and CO emissions and the increase in NOx emissions should be adjusted linearly from the values in Section 3.1.1.1 and Table 3-1.

As was done with ethanol blends, the potential increase in exhaust aldehydes has been accounted for by assuming it would increase exhaust ozone potential to the same degree as the presence of exhaust alcohol would decrease the ozone potential. In other words, the net effect of increases in exhaust aldehydes and exhaust alcohol is assumed to be zero.

3.1.2.2 Evaporative HC Emissions

Table 3-3 contains the evaporative emission effects of methanol blends, which do not depend on exact oxygen content.

Addition of methanol to a base gasoline generally results in an increase of 2-3 psi RVP. However, the resultant blend is subject to ASTM volatility parameters unlike gasohol. Thus, the volatility of the blend is adjusted (e.g., by prior butane removal) to decrease the volatility. For the purposes of this document, it can be assumed that the RVP of a methanol blend will be the same as that of the gasoline it displaces in the market place if gasoline in the area is on average about at the ASTM RVP limit. However, if various fuel surveys (such as the MVMA or NIPER summer surveys) show that gasoline in that area is under the ASTM limit (e.g., by about 0.76 psi), then the numbers in the tables for +0.76 psi RVP for either the 9 or 11.5 psi RVP cases should be used. Larger or smaller RVP margins can be approximated by linear interpolation or extrapolation. EPA assumes that methanol blend refiners will utilize all of the RVP allowed by the ASTM limit, even if for various reasons refiners of the gasoline now sold in the same area do not.

The lower molecular weight of methanol versus gasoline evaporative hydrocarbons (32 versus 64) reduces the mass of diurnal evaporative emissions. Evaporative emissions from a vehicle using a methanol blend consist of about 15% methanol, so the molecular weight adjustment (for diurnal emissions) has been applied to this fraction of the evaporative emissions in Table 3-3 and the subsequent adjustment factor tables. Methanol, like ethanol, increases the percentage of fuel evaporated at 160°F. This has also been accounted for in the values shown in Table 3-3. Molecular differences between methanol and true hydrocarbons with respect to ozone formation have also been reflected in the adjustment factor tables, on the same basis as for methanol fueled vehicles in Section 3.2.2 below.

If the market penetration of a methanol blend is other than 50% or 100%, a commingling value should be determined by use of a quadratic equation through the three points given for 0%, 50%, and 100% market share. Based on limited data, it is assumed that methanol blends have no commingling effects with either ethanol blends or MTBE blends. Thus, if methanol blends are sold with ethanol blends and/or MTBE blends, commingling effects should be calculated as described in Appendix B.

3.1.3 11% MTBE Blends (2% Oxygen)

While EPA has granted a waiver for use of 7% MTBE, EPA subsequently issued rules permitting use of all alcohol and ether-type oxygenates other than methanol in gasoline up to a level corresponding to 2% oxygen, ruling that such levels would be substantially similar to gasoline.[14] A 2% oxygen level would permit use of an 11% MTBE blend, which is therefore the maximum level presently permitted. A new waiver application would have to be submitted to EPA and approved for use of higher MTBE levels.

3.1.3.1 Exhaust HC, CO, and NOx Emissions

It is assumed that the changes in exhaust emissions from use of 11% MTBE with a 2% oxygen level will be directly proportional to the amount of oxygen present. Thus, the values are a linear proportion of the earlier values for ethanol and methanol blends in Sections 3.1.1.1 and 3.1.2.1 and are shown in Table 3-1. The basis for this assumption is as follows.

An 11% MTBE blend has less oxygen and, therefore, less potential for enleanment of the air/fuel mixture. Among a large group of vehicles, the actual reductions should logically show a trend of diminishing returns from higher and higher oxygen levels as more and more cars are pushed into the lean region for more of their operation, so that further oxygen has less or no effect. Most of the existing data on oxygenated blends is for fuels in the 3.5% - 3.7% oxygen range, and if a linear effect is assumed from zero up to 3.7%, it will provide a conservative estimate of the effect of 2.0% oxygen. Since the issue is whether a substantially greater than linear emission reduction occurs at 2.0% oxygen, EPA has reviewed the data on vehicles tested with both 2.0% and 3.7% oxygen fuels, and its judgment is that the available data are currently neither extensive enough, consistent enough, nor dramatic enough, in showing a clear departure from linearity to risk overestimating the benefits at this time. Therefore, EPA assumes a linear relationship between exhaust emissions and oxygen content in the zero to 3.7% range of fuel oxygen. For a more detailed discussion of this data and its analysis, refer to the technical support report that will be released soon after this document.[25] This issue is being investigated further in EPA and industry programs designed to obtain more data with both fuels.

3.1.3.2 Evaporative HC Emissions

Addition of MTBE to gasoline does not result in increased RVP; in fact, some limited evidence indicates that there may be a slight decrease in RVP. However, 11% MTBE will increase the 160°F distillation point.[15] This is expected to result in increased evaporative emissions as mentioned in Section 3.1.1.2.[2] Values for this emission impact are given in Table 3.4.

3.1.4 Simultaneous Marketing of Ethanol, Methanol and MTBE Blends

The exhaust and evaporative emission impacts of partial marketing of only a single blend can be calculated easily as explained above using the appropriate tables. The factor for commingling included in the tables is relatively straightforward for a single blend.

However, simultaneous marketing of several different types of blends with or without gasoline also being sold raises the possibility of different types of commingling, such as of one blend with another. However, most of the available data on commingling effects are for mixtures of individual oxygenate blends with gasoline with only a small amount of data on mixtures of ethanol blends with MTBE blends or methanol blends. Based on the few data points available, it will be assumed that mixtures of ethanol blends with MTBE blends or with methanol blends act linearly. In other words, there is no commingling effect, and emission effects in an all-blends program can be calculated by doing a simple market share weighting of the individual blend effects.

If non-oxygenated gasoline is expected to be sold at the same time as more than one type of blend, non-linear commingling effects on the gasoline will occur but a more complicated calculation is required to account for the absence of commingling effects among the blends. The required calculation is described in Appendix B.

3.2 Fuels Requiring Special Vehicles

The following fuels cannot be used in typical current technology gasoline fueled vehicles without some degree of mechanical modifications to the vehicles. Therefore, these fuels would more likely be used initially in fleet applications (with new vehicles) rather than in area-wide applications with typical in-use (both old and new) vehicles.

Due to the limited quantity of available emissions data on these fuels and the fact that the vehicle technologies for use of these fuels are undergoing rapid advances, the emission benefits that follow are subject to change as new information arises. Given the anticipated pace of research and EPA's desire to provide a stable set of assumptions through the upcoming cycle of SIP development, review, and approval, it is unlikely that EPA will revise these benefit estimates downward by a significant degree prior to completion of this planning cycle.

3.2.1 Compressed Natural Gas (CNG) Vehicles

Compressed Natural Gas (CNG) consists mainly of methane with smaller quantities of ethane and propane. Very limited data suggest a large fraction (approximately 80%) of the exhaust consists of methane. Since methane is photochemically non-reactive except over long periods, a potential exists for lower urban ozone formation from the exhaust emission products. Also, the combustion characteristics of CNG (e.g., leaner flammability limits, better mixing with the intake air for combustion) could lead to both lower HC and CO emissions. The limited data from several different studies on NOx emissions with CNG are conflicting. While some data indicate that a decrease of NOx up to 20% might occur, the majority of the data indicate an increase (up to 80%) with CNG. Due to the leaner combustion as well as methane's relatively high flame temperature, an increase in NOx would be expected.

Most of the work done so far has been on retrofitting gasoline fueled vehicles to operate on CNG. Limited consideration has been given to manufacturing new vehicles designed to operate specifically on CNG. This section discusses factors affecting the retrofit scenario in some detail. The changes in emissions for CNG vehicles given later though may be applied to either new or retrofitted vehicles. Very limited data are available on emissions from CNG vehicles, however, so EPA would consider using different credits if adequate data are provided to support them. It is likely that new dedicated CNG vehicles would be able to achieve lower emission rates than those presented here.

While numerous firms produce and market kits for converting gasoline vehicles to operate on either gasoline or CNG, very little reliable data on emissions of converted vehicles on CNG and gasoline have been obtained. There is some reason to suspect that some kits, when installed improperly, may result in increases in emissions when operated on gasoline, and emissions on CNG which are not significantly lower if at all. However, if an area were to make CNG conversions a significant part of its attainment strategy, it would be appropriate and quite feasible to ensure that only proven-effective kits are used and that only competent mechanics install them.

Also, CNG can result in a deterioration of driveability and a power loss. Fleet operators may re-adjust the vehicles for richer operation to improve driveability. Thus, it would be necessary to have a procedure implemented with CNG use assuring that vehicles remain correctly adjusted. EPA would be available to give advice in this regard, and may at a later date even require or recommend specific safeguards and specifications for large-scale conversion programs if they are to be part of an approvable SIP.

The following estimates may be used to predict the emission changes expected when operating vehicles on CNG. The base for applying the exhaust HC change is the MOBILE3 estimate of non-methane HC from gasoline-fueled vehicles. Due to lack of high altitude data, it may be assumed for now that the same percentage changes apply to both low and high altitude, as has been found for low level gasoline-oxygenate blends.

HC Exh:	-40%	(Includes effect of reduced reactivity due to high methane fraction)
CO:	-50%	
NOx:	+40%	(NOx emissions generally increase with CNG and this number is an average of the data range)
HC Evap:	-100%	(assumes no evaporative emissions)

EPA will allow areas to assume that, when operating dual fuel vehicles on gasoline, emissions are not affected by conversion. Table 4-18 summarizes the multiplicative adjustment factors corresponding to these reductions.

In any practical conversion program most conversions will likely be of new or fairly young vehicles, since these are the types operated by self-fueling fleets and since the economics of conversion are more favorable as the length of time in service increases. Although the available data are mostly from light-duty trucks and vehicles, EPA believes that the above percentage reductions may be reasonably appropriate for conversions of recent and future technology gasoline-fueled passenger cars, light-duty trucks and vans, and heavy-duty trucks and buses. Furthermore, these percentage reductions are assumed to apply at all ages.

3.2.2 Methanol Fueled Vehicles (FFV's, M85, M100, etc.)

The use of methanol as an alternative fuel has received increasing interest in recent months from legislative, environmental, and automotive groups, as well as the methanol supply industry. Numerous prototype vehicles, fleet demonstrations, and legislative proposals have been initiated. EPA has started a rulemaking to set standards to provide planning stability for the automakers. The proposed standards will in effect regulate a weighted sum of hydrocarbons, methanol, and formaldehyde. The numerical standards for the weighted sum of "organics" will be equivalent to the existing hydrocarbon standards for gasoline-fueled vehicles in terms of the total amount of carbon which can be emitted in the form of partially burned or unburned fuel. The CO and NOx standards will be the same as for gasoline-fueled vehicles. These standards will apply to methanol-fueled vehicles and to flexible fueled vehicles (FFV's) when running on methanol.[29] EPA believes that lower emission levels than required by the proposed standards are possible, and promising technology for even lower levels is under development.

This section will describe the range of emission effects expected from use of fuels with high concentrations of methanol (or possibly ethanol) in vehicles designed or modified to use such fuels. A SIP mandate for such vehicles could take a variety of forms as to the type of vehicles required. For instance, it might state (explicitly or by having no other provision) that the methanol fueled vehicles that will displace gasoline fueled vehicles would just meet the proposed EPA standard for methanol fueled vehicles, or it could provide assurance that the vehicles will be designed for lower emission levels than would result just from the proposed EPA standards. Therefore, the cases to be presented include ones that go beyond just meeting the proposed EPA standard. The details of how this would be accomplished (assuring that vehicles would be cleaner than the EPA standard) technically, legally, and administratively are beyond the scope of this document.

Regarding the feasibility/availability of dedicated methanol vehicles, it should be noted that some comments were received by EPA stating that production of such vehicles for consumer use is not expected in the near future. Planners wishing to incorporate the use of such vehicles in air quality projections are cautioned to make sure vehicle technology projections are realistic in terms of which technologies are actually available.

The actual credits to be applied would depend on the emission levels of whatever vehicle technology is proposed by a locality, with adequate supporting data. For scenarios other than the three presented here, credits can be determined through individual consultation with EPA.

The use of a high concentration of methanol or neat methanol results in exhaust and evaporative emissions that are primarily methanol. The exhaust may also contain elevated levels of formaldehyde. However, the presence of any gasoline in the blend results in significant hydrocarbon emissions too. The impact of this changed mix and amount of emitted species is addressed in the following sections.

Data are not sufficient to indicate that either CO or NOx emissions are changed with use of a dedicated or flexible fueled vehicle.[16,17,18,19,20] In fact, at low temperatures current technology dedicated vehicles and FFV's may have poorer CO performance than gasoline vehicles in the absence of low temperature standards for either vehicle type. Since this is currently an area of uncertainty, however, EPA will allow states to assume equal CO and NOx emissions for methanol and gasoline vehicles.

3.2.2.1 City-specific Ozone Reduction Determinations

The photochemical reactions of normal auto exhaust hydrocarbons, methanol, and formaldehyde can vary from city to city depending on the HC/NOx ratio, atmospheric conditions, and other parameters. Due to the city-specific nature of emissions reactivity, ideally a planner would use a photochemical dispersion model for the urban area of interest to determine potential ozone reductions from use of dedicated methanol vehicles and/or flexible fueled vehicles. EPA endorses the superiority of this approach and recommends its use by areas capable of following it. However, planning realities require the availability of more workable or default assumptions and approaches, such as are made available for other aspects of the planning task. Default benefits representing EPA's best judgment of an average case are presented in the following sections, and these may be used with no city-specific defense of their applicability. Areas wishing to conduct the more accurate city-specific analysis should consult with EPA at each step. These default values are considered an interim approach, and city specific photochemical dispersion models (e.g., Airshed) should be used as they become available.

3.2.2.2 Default Ozone Reduction Estimates for Vehicles Just Meeting The EPA Standards For Methanol Vehicles

The first case to be examined is for light duty vehicles that just meet the proposed EPA carbon-based organics emissions standard for methanol fueled vehicles. This standard is based on the fact that 0.41 g/mile HC represents 0.354 g/mile carbon assuming a carbon:hydrogen ratio of 1:1.85, and a methanol-fueled vehicle would, therefore, also emit no more than 0.354 g/mile carbon. This is expected to be the most likely case that planners could have available to them in the next few years. For instance, it would probably apply to FFV's operating on M85 as well as dedicated methanol vehicles operating on M85.

A dedicated methanol vehicle is one that uses only fuel composed of at least 85% methanol. Even though the comments EPA received in response to its proposed methanol rulemaking indicated that such vehicles could realize most cost and performance advantages by using as little as 50% methanol, the vehicles currently being designed and built use from 85% to 100% methanol. Flexible fueled vehicles (FFVs) can use either gasoline fuel or an alcohol/gasoline blend up to 85% or 100% methanol (or ethanol). The vehicles are designed to sense how much alcohol is in the mixture and make appropriate engine adjustments for proper combustion.

There are a number of issues specifically related to use of FFV's that a SIP would need to cover if FFV use is to be part of the SIP. For instance, FFV's would probably be designed to need M85 in the winter for cold driveability, and thus would not be expected to be able to achieve the low or intermediate emission levels that follow this section. In the summer months, however, EPA will allow the assumption of M100 fuel in FFV's if M100 fuel is mandated in the SIP. This would increase the likelihood of FFV's being able to meet the intermediate and possibly even the low emission estimates that follow.

It is important when estimating future emission reductions for flexible fueled vehicles to credibly predict what fraction of the time the vehicles will operate on a methanol mixture versus gasoline, since no emission reductions occur with use of gasoline. It is also important to confirm what percentage methanol is being used. Predicting future fuel composition and use is easiest when the SIP contains regulations with specific mandates for both aspects. Items such as methanol sales records should be used for tracking purposes to determine the mileage accumulated with the methanol blends. If the SIP allows less than M85 and the vehicles in question match one of the certification emission levels only on M85, the SIP must justify an estimate of the average methanol content and percentage of time operated on that fuel and then proportion the benefit accordingly. For tracking methanol use retrospectively, the two aspects (methanol content and time it is used) can be combined, and all that needs to be determined is the percent of total fuel used that was methanol.

The following are the individual emission levels which EPA predicts would be exhibited under certification conditions (e.g., properly maintained and used) for a vehicle certified to meet the proposed combined organics standard, CO standard, and NOx standard. This prediction is subject to uncertainty, since EPA will not directly regulate the amounts of HC, methanol, and formaldehyde individually.

Just Meeting the Proposed EPA Organics Standard
For Methanol Fueled Light Duty Vehicles

	Certification Exhaust	Certification Evaporative
HC	0.15 g/mile	1.08 g/test (0.07 g/mile)
Methanol	0.55 g/mile	2.19 g/test (0.16 g/mile)
Formaldehyde	0.048 g/mile	none

In selecting default estimates for the ozone reduction achieved by methanol vehicles with these certification emission levels, EPA considered several factors each of which causes some uncertainty. First, the engine designs and emission control system designs which manufacturers would use to achieve these emission levels are not yet known with certainty. FFV's may dominate, but perhaps not to the exclusion of dedicated vehicles. Fuel injection will most likely be used on all vehicles, but other features may vary. Second, the relationship between certification emission levels and in-use emission levels may be different from the relationship with gasoline vehicles, which is itself not fully known for the most recent designs. Dedicated methanol vehicles should be less exposed to lead in their fuel, and FFV's may be also, which will limit catalyst deactivation relative to gasoline vehicles. Deliberate catalyst removal may also be less frequent, since much of the catalyst removal problem on gasoline vehicles is associated with deliberate misuse of leaded fuel. Third, EPA considered the results of the available studies of the photochemical effects of methanol vehicle emissions relative to gasoline vehicle emissions. These studies vary in their sophistication and in their results, but on the whole support an assumption of a substantial difference in overall contribution to ozone formation.

In light of the above factors, EPA will accept the use of the following estimates of the equivalent HC reductions for vehicles just meeting the EPA standards. These percentages should be applied to the non-methane HC output for MOBILE3, and the results treated as non-methane.

VOC Exhaust	- 34%
VOC Evaporative (compared to 11.5 psi summer gasoline)	- 71%
VOC Evaporative (compared to 9.0 psi summer gasoline)	- 32%

Methanol-fueled light-duty trucks and heavy-duty vehicles just meeting the proposed standards for their classes may claim the same percentage reduction credits.

3.2.2.3 Default Ozone Reduction Estimates for Vehicles With Emissions Well Below the EPA Standards

The following are the individual emission levels under certification conditions (e.g., properly maintained and used) which define this scenario.

Emissions Well Below the EPA Standards

	Certification Exhaust	Certification Evaporative
HC	0.020 g/mile	0.0 g/test
Methanol	0.20 g/mile	1.0 g/test (0.07 g/mile)
Formaldehyde	0.010 g/mile	none

In order to meet these emission levels a methanol vehicle would most likely incorporate engine design features optimized to take full advantage of pure methanol's excellent combustion characteristics (high octane, wide flammability limits, high flame speed, low flame temperature, etc.). Design features would likely include high compression, lean burn combustion, and an advanced fuel injection system, and could include concepts such as turbocharging or supercharging, methanol dissociation, cooling system modification, etc. Also, the vehicle would have very low formaldehyde emissions possibly due to use of a modified catalyst configuration (size, composition, or location). The vehicle would have to be designed to have good driveability even though it would be leaned out enough to have sufficiently low NOx emissions without the use of a reduction catalyst. EPA expects that dedicated M100 vehicles are the most likely technology to achieve these levels, but if FFV or M85 vehicles are certified with test results this low, the same credits would apply.

However, comments received from the California Air Resources Board point out that in some areas the control of NOx emissions is important enough to ozone control that such vehicles may need to operate at stoichiometry to allow use of 3-way catalysts for maximum NOx control.

A low emitting vehicle meeting the above emission criteria may claim the following default non-methane HC reduction credits, calculated as in the prior example.

VOC Exhaust	- 83%
VOC Evaporative (compared to 11.5 psi gasoline)	- 93%
VOC Evaporative (compared to 9.0 psi gasoline)	- 85%

3.2.2.4 <u>Default Ozone Reduction Estimates for Vehicles With Intermediate Emission Levels</u>

This case could apply to vehicles that could not meet the very low emission levels in the previous section, but were still capable of substantially lower emissions than vehicles just able to meet the standard. This could include FFV's and dedicated methanol (e.g., M85 or M100) vehicles.

The following are the individual emission levels under certification conditions (e.g., properly maintained and used) which define this scenario.

	Certification Exhaust	Certification Evaporative
HC	0.09 g/mile	0.35 g/test (0.02 g/mile)
Methanol	0.34 g/mile	1.5 g/test (0.11 g/mile)
Formaldehyde	0.023 g/mile	

The default reduction credits for this case are as follows:

VOC Exhaust	- 68%
VOC Evaporative (compared to 11.5 psi gasoline)	- 78%
VOC Evaporative (compared to 9.0 psi gasoline)	- 48%

Table 4-18 summarizes the adjustment factors for CNG vehicles (given in Section 3.2.1) and methanol vehicles.

4.0 CALCULATION OF FLEET EFFECTS

4.1 General Approach and Model Year-Specific Adjustment Factors

The general approach for calculating emission changes due to use of alternative fuels is based on MOBILE3 which is the model the States use to calculate the mobile source emission portion of their SIPs. MOBILE3 calculates emissions from in-use motor vehicles for the calendar year of interest. The purpose of this section is to present factors to adjust a special version of the MOBILE3 output to account for alternative fuels. Detailed examples of this method are provided in Appendix C. Appendix D provides an in-depth explanation of (a) the calculation procedure used to create Tables 4-1 to 4-17 and (b) how to combine the appropriate information for a given scenario; this can also be used to automate the full calculation procedure.

Before discussing the adjustment factors for MOBILE3, it is important to determine the technology split in the various vehicle classes. This technology split is important since the change in vehicle emissions with oxygenated fuels depends on the vehicle technology as mentioned in Section 3. Table 4-1 lists the technology splits for vehicles from the pre-1975 through 1990+ model years. The different technologies considered in Table 4-1 are non-catalyst, open-loop oxidation catalyst vehicles with carburetors, open-loop oxidation catalysts with fuel injection, closed-loop 3-way catalyst vehicles with carburetors, and closed loop 3-way catalyst vehicles with fuel injection. For exhaust emissions, it is a reasonable approximation to assume that a technology type's share of the model year's emissions is the same as its share of that year's sales. However, carbureted and fuel injected vehicles have quite different evaporative emissions. Greater accuracy can be achieved without undue complication by recognizing and accounting for this difference. Table 4-2 presents EPA's current best estimates of evaporative emissions from carbureted and fuel injected vehicles on 11.5 psi and 9.0 psi non-oxygenated gasoline.

Table 3-1 already listed the general percentage changes assigned to each technology class for exhaust emissions for ethanol, methanol, and MTBE blends. On a percentage basis these numbers are the same for low and high altitude, but since high altitude CO emissions are greater than low altitude, the g/mile changes would be greater at high altitude. Table 3-2 lists the evaporative emission assumptions by technology for ethanol blends. These changes were determined for each technology by adding the effects of RVP on diurnal and hot soak emissions as well as the effect of distillation curve (% evaporated at 160°F) on hot soak mass emissions. The distillation effect has been adjusted so as not to double count any RVP-only effect on hot soak emissions.

Ethanol Blends - The final results for ethanol blends are given in Tables 4-3 to 4-9, in the form of adjustment factors to be applied to individual model year emission levels of individual vehicle types (e.g., LDGV, LDGT, etc.). Table 4-3 contains the percentage change in exhaust "volatile organic compounds" (or, for the purposes of MOBILE3, exhaust non-methane HC) for vehicles in model years pre-1975 through 1990+. Tables 4-4 through 4-7 list similar information for vehicles in these model years for vehicle evaporative emissions when using ethanol blends. Factors such as the RVP level of the blend and percent market share of the blend (i.e., the commingling effect for either 50% or 100% market share) are included in these tables. Tables 4-8 and 4-9 give exhaust CO and NOx emissions changes with ethanol blends.

These tables were constructed using the individual technology effects from Tables 3-1 and 3-2 and weighting those effects by the technology mix (non-catalyst/OL/CL for exhaust, Carb/FI for evap) for each model year for each vehicle category (LDGV, LDGT1, LDGT2, and HDGV).

Methanol Blends - Since the exhaust effects of methanol blends are the same as for ethanol blends at a given RVP, Tables 3-1, 4-3, 4-8, and 4-9 also apply to methanol blends. Regarding evaporative emission effects, Tables 3-3 and 4-10 through 4-13 give similar information for methanol blends.

MTBE Blends - Tables 3-1, 3-4 and 4-14 through 4-17 give the corresponding exhaust and evaporative emission information for MTBE blends.

CNG and Methanol - Table 4-18 provides adjustment factors for CNG and methanol fueled vehicles. Because the adjustments for CNG vehicles, FFV's, and current technology and advanced technology dedicated methanol vehicles do not depend on the technology mix of gasoline vehicles, they do not depend on model year. The general approach is the same, however. Appropriate adjustment factors for each affected model year have been derived from the relevant reductions given in the text in Section 3.2.

These calculations apply to both low and high altitude areas. However, for high altitude areas, the high altitude input flag of MOBILE3 should be used.

To use the information in, for example, Table 4-8 to calculate an overall fleet effect, it is necessary to first obtain a special MOBILE3 output showing model year-specific g/mile emission levels and VMT weighting factors. (This MOBILE3 run should include the vehicle inspection program, if any, that is or will be in operation on the evaluation date.) Then the model year adjustment factors from the appropriate table should be applied to the individual model year output for oxygenated blends. This must be repeated for each vehicle type. The model year factors should then be recombined across model years and then vehicle types. For both steps, VMT weighting factors are used. This adjustment and recombination procedure requires hand calculation.

This methodology will work for 100% of one or some model years using CNG, FFV, 85% methanol, or 100% methanol. It will also work for the oxygenated blends for the cases for which there are tables. These cases include 100% market share of one of the three oxygenate blends or 50% market share of either the ethanol or methanol blends. Other cases are covered in Appendix A.

4.2 Partial Penetration by One Blend or Vehicle Type

For market shares of oxygenated blends not listed in the table, the effects of the blends on evaporative emissions must be calculated. This calculation is simplest for MTBE where one can interpolate linearly for the effects between 0% and 100%, since there are no commingling effects. For either the ethanol or methanol blends with gasoline, one must make a quadratic interpolation using the 0%, 50%, and 100% points since this relationship is not linear due to commingling effects.

It is important to note that the 50% market penetration of an ethanol or methanol blend with gasoline results in a greater per-vehicle effect on evaporative VOC for the blend fueled fraction of the fleet than the 100% market share case. This can be seen by comparing Tables 4-4 and 4-6. The reason for this is that with an ethanol or methanol blend market share of less than 100% some degree of commingling is expected from consumers mixing the alcohol blend with non-oxygenated gasoline (such as by filling their tank with non-oxygenated gasoline when the previous fill-up was with an ethanol blend). Therefore, a program with no such commingling would yield the greatest benefits.

If the blend market share varies by model year or vehicle type, the user must interpolate the adjustment factors before they are applied to the model year g/mile emission levels. If it is the same for each model year and vehicle type, a single interpolation on the overall fleet emission level is acceptable.

If one blend or vehicle type (e.g., CNG, methanol) is used for only some model years, the adjustment should be applied only for those model years. Interpolation may be needed for that model year if there is less than 100% usage.

For partial penetration of alternative fuel vehicles (e.g., CNG, methanol), one can proportion the adjustment factors or the final fleet g/mile value accordingly.

4.3 Simultaneous Marketing of MTBE, Ethanol, and/or Methanol Blends

Based on the limited amount of test data that has been collected on commingling of these oxygenates, it appears that no significant non-linear RVP increase results from mixtures of MTBE, ethanol, or methanol blends.[27,28] Therefore, any all-blends scenario can be analyzed by market share weighting the individual blends' "100% Use" adjustment factors from Tables 4-3 to 4-17.

A scenario in which non-oxygenated gasoline is marketed at the same time as two blends can be analyzed using the method described in Appendix B.

4.4 Blends and CNG, FFV, M85 and/or M100 in Same Model Year

Here each model year should be divided into two or more groups based on the sales split between gasoline vehicles and alternative fuel vehicles. An adjustment factor should be selected (or calculated if necessary) for the gasoline portion based on expected blend use. This adjustment factor should be combined with the standard adjustment factors for CNG, FFV, current technology methanol vehicles, and advanced technology methanol vehicles using the new vehicle sales mix.

5.0 OBTAINING SPECIAL MOBILE3 OUTPUT

To use the method and numerical adjustment factors provided in earlier sections, it is necessary to have more detailed output than can be obtained with the standard MOBILE3 (or MOBILE4) program. Specifically, output is needed which shows for a given pollutant the emission factor for each model year/vehicle type, and that model year's share of the VMT from that vehicle type. VMT shares among vehicle types are also needed but are available in the standard MOBILE3 output. For VOC, exhaust and evaporative emissions must be shown separately for each model year so that the separate adjustments can be made.

While it is possible for a user to modify the MOBILE3 (or MOBILE4) code to generate the required output, EPA believes it will be more convenient and less error prone for most users to obtain from EPA a magnetic tape containing the Fortran source code for a modified MOBILE3 (or MOBILE4) which can produce both the standard types of output and the special version required for using this method. Users should contact Joseph H. Somers or Jonathan Adler, U.S. Environmental Protection Agency, 2565 Plymouth Road, 48105, (Telephone 313-668-4321) for more information.

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28. G. E. Crow and B. C. Davis, "Environmental Effects of Oxygenates," Presentation given at the 1987 National Conference on Fuel Alcohol and Oxygenates, September 30 - October 1, 1987.

29. Standards for Emissions From Methanol-Fueled Motor Vehicles and Motor Vehicle Engines; Notice of Proposed Rulemaking, Federal Register, 51, 168, August 29, 1986.

30. "Ethanol Commingling," EPA Memo from Craig Harvey, Technical Support Staff to Phil Lorang, Chief, Technical Support Staff, December 21, 1987.

31. "Ethanol Reactivity - Comments of the Ad Hoc Ethanol Committee," EPA Memo from Penny M. Carey, Technical Support Staff to Phil Lorang, Chief, Technical Support Staff, December 18, 1987.

32. ARCO waiver application for Oxinol.

Table 3-1

Technology-Specific
Exhaust Effects of Blends
Percent Change from Gasoline
(low and high altitude)

Technology	3.7% Oxygen (10% Ethanol or 5% Methanol/Cosolvent Blends)					2.0% Oxygen (11% MTBE Blends)		
	CO			VOC		CO		VOC
	Same RVP	+0.76 PSI	NOx	Same RVP	+0.76 PSI	Same RVP	NOx	Same RVP
Non-Catalyst	-24.5%	-22.8%	+3.8%	-5.5%	-4.2%	-13.2%	+2.1%	-3.0%
Open-Loop Catalyst	-34.9	-33.4	+4.0	-15.6	-14.5%	-18.9	+2.2	-8.4
Closed-Loop	-21.4	-17.2	+8.1	-5.1	-2.4%	-11.6	+4.4	-2.8%

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Table 3-2

Evaporative VOC Technology-Specific Effects of 10% Ethanol Blends[a] Percent Change From Gasoline

100% Share (no commingling)	11.5 RVP Base		9.0 RVP Base	
	Same RVP	RVP + 0.76	Same RVP	RVP + 0.76
Diurnal				
Carb	-9.66	+80.1	-9.66	+41.13
F.I.	-9.66	+122.2	-9.66	+42.67
H. S.				
Carb	+14.85	+35.28	+14.85	+25.52
F. I.	-5.70	+20.18	-5.70	+34.01
50% Share (max commingling)				
Diurnal				
Carb	+20.97	+96.21	-2.39	+51.72
F. I.	+33.92	+144.9	-3.32	+55.10
H. S.				
Carb	+18.18	+39.57	+16.20	+28.47
F. I.	+1.57	+24.97	+0.30	+42.36

a These effects include adjustments for lower molecular weight of ethanol and lower number of carbons/gram relative to gasoline vapor. For hot soak, adjustments for molecular weight are not used, but for carbureted vehicles an adjustment for distillation (% evap @160°F) is included.

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Table 3-3

Technology-Specific Effects of 3.7% Oxygen Methanol/Cosolvent Blends: Evaporative VOC[a]

(percent change including reactivity adjustment)

100% Share (no commingling)	11.5 RVP Base		9.0 RVP Base	
	Same RVP	RVP + 0.76	Same RVP	RVP + 0.76
Diurnal				
Carb	-18.79	+61.89	-18.79	+26.88
F.I.	-18.79	+99.76	-18.79	+28.26
H.S.				
Carb.	-3.19	+12.45	-3.19	+3.37
F.I.	-12.20	+11.90	-12.20	+24.77
50% Share (Max Commingling)				
Diurnal				
Carb.	+28.60	+111.4	-2.94	+58.94
F.I.	+50.69	+189.1	-1.64	+68.28
H.S.				
Carb.	+6.90	+24.93	+1.69	+12.33
F.I.	+0.05	+25.92	+6.25	+48.66

a These effects include adjustments for lower molecular weight of methanol and lower number of carbons/gram relative to gasoline vapor. For hot soak, adjustments for molecular weight are not used, but for carbureted vehicles an adjustment for distillation (% evap @160°F) is included. The no commingling scenarios are based on Reference 2, and the maximum commingling scenarios adjust the no commingling estimates per Reference 21 assuming 20% full tanks at refueling and a reasonable degree of brand loyalty.

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Table 3-4

Technology-Specific Effects of
11% MTBE Blends: Evaporative VOC[a]

(percent change, matched to any base RVP)

Diurnal	
Carbureted	+1.78
Fuel Injected	+1.78
H.S.	
Carbureted	+12.82
Fuel Injected	-1.90

a These effects include adjustments for greater molecular weight of MTBE and lower number of carbons/gram relative to gasoline vapor. For hot soak, adjustments for molecular weight are not used, but for carbureted vehicles an adjustment for distillation (% evap @160°F) is included.

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Table 4-1

Exhaust and Evaporative Emissions Technology Mix (Sales-Based)

Model Year	Technology Mix*			
	LDGV	LDGT1	LDGT2	HDGV
	A/B/C/D/E	A/B/C/D/E	A/B/C/D/E	A/B
pre-1975	100/0/0/0/0	100/0/0/0/0	100/0/0/0/0	100/0
75	20/75/5/0/0	30/70/0/0/0	100/0/0/0/0	100/0
76	15/80/5/0/0	20/80/0/0/0	100/0/0/0/0	100/0
77	15/80/5/0/0	25/75/0/0/0	100/0/0/0/0	100/0
78	10/85/5/0/0	25/75/0/0/0	100/0/0/0/0	100/0
79	10/85/5/0/0	20/80/0/0/0	0/100/0/0/0	100/0
80	5/83/7/5/0	20/79/1/0/0	0/100/0/0/0	100/0
81	0/28/0/63/9	0/96/1/3/0	0/100/0/0/0	100/0
82	0/33/0/50/17	0/79/1/20/0	0/100/0/0/0	100/0
83	0/24/0/48/28	0/70/0/30/0	0/90/0/10/0	100/0
84	0/6/0/55/39	0/72/0/26/2	0/72/0/26/2	100/0
85	0/6/0/39/55	0/63/0/25/12	0/63/0/25/12	100/0
86	0/7/0/26/67	0/41/9/15/35	0/41/9/15/35	100/0
87	0/1/0/24/75	0/14/5/13/68	0/14/5/13/68	26/74
88	0/1/0/20/79	0/14/5/13/68	0/14/5/13/68	26/74
89	0/1/0/15/84	0/14/5/13/68	0/14/5/13/68	26/74
90+	0/1/0/10/89	0/14/5/13/68	0/14/5/13/68	26/74

* A Non-catalyst
B Open-loop carbureted
C Open-loop fuel injected
D Closed-loop carbureted
E Closed-loop fuel injected.

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Table 4-2

Baseline Non-Oxygenated
Gasoline Evaporative HC Emissions

	RVP			
	9.0	9.76	11.5	12.26
Carbureted				
Hot Soak, g	2.46	2.77	4.27	5.25
Diurnal, g	2.65	4.14	9.09	18.12
Total, g/mile	0.326	0.405	0.711	1.098
Fuel Injected				
Hot Soak, g	0.95	1.35	2.66	3.39
Diurnal, g	1.83	2.89	7.94	19.53
Total, g/mile	0.152	0.225	0.516	0.960

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Table 4-3

Low and High Altitude Adjustment Factors for 10% Ethanol or 3.7 Oxygen Methanol Blends by Model Year and Type: Exhaust VOC

	Ratio of Blend to Base Exh VOC (3.7% O2, Matched RVP)				Ratio of Blend to Base Exh VOC (3.7% O2, RVP + 0.76 psi)			
	Matched RVP				RVP + 0.76 RVP			
MY	LDGV	LDGT1	LDGT2	HDGV	LDGV	LDGT1	LDGT2	HDGV
<75	0.9450	0.9450	0.9450	0.9450	0.9580	0.9580	0.9580	0.9580
75	0.8642	0.8743	0.9450	0.9450	0.8756	0.8859	0.9580	0.9580
76	0.8592	0.8642	0.9450	0.9450	0.8705	0.8756	0.9580	0.9580
77	0.8592	0.8693	0.9450	0.9450	0.8705	0.8808	0.9580	0.9580
78	0.8541	0.8693	0.9450	0.9450	0.8653	0.8808	0.9580	0.9580
79	0.8541	0.8642	0.8440	0.9450	0.8653	0.8756	0.8550	0.9580
80	0.8543	0.8642	0.8440	0.9450	0.8662	0.8756	0.8550	0.9580
81	0.9196	0.8472	0.8440	0.9450	0.9421	0.8586	0.8550	0.9580
82	0.9144	0.8650	0.8440	0.9450	0.9361	0.8792	0.8550	0.9580
83	0.9238	0.8755	0.8545	0.9450	0.9470	0.8913	0.8671	0.9580
84	0.9427	0.8734	0.8734	0.9450	0.9687	0.8889	0.8889	0.9580
85	0.9427	0.8829	0.8829	0.9450	0.9687	0.8998	0.8998	0.9580
86	0.9417	0.8965	0.8965	0.9450	0.9675	0.9155	0.9155	0.9580
87	0.9480	0.9291	0.9291	0.8703	0.9748	0.9530	0.9530	0.8818
88	0.9480	0.9291	0.9291	0.8703	0.9748	0.9530	0.9530	0.8818
89	0.9480	0.9291	0.9291	0.8703	0.9748	0.9530	0.9530	0.8818
90+	0.9480	0.9291	0.9291	0.8703	0.9748	0.9530	0.9530	0.8818

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Table 4-4

Low and High Altitude Adjustment Factors for 10%
Ethanol Blends by Model Year and Type: Evaporative VOC

(100% Use of Blend)

	9.0 psi (matched RVP)				11.5 psi (matched RVP)			
MY	LDGV	LDGT1	LDGT2	HDGV	LDGV	LDGT1	LDGT2	HDGV
<75	1.0845	1.0845	1.0845	1.0845	1.0477	1.0477	1.0477	1.0477
75	1.0808	1.0845	1.0845	1.0845	1.0432	1.0477	1.0477	1.0477
76	1.0808	1.0845	1.0845	1.0845	1.0432	1.0477	1.0477	1.0477
77	1.0808	1.0845	1.0845	1.0845	1.0432	1.0477	1.0477	1.0477
78	1.0808	1.0845	1.0845	1.0845	1.0432	1.0477	1.0477	1.0477
79	1.0808	1.0845	1.0845	1.0845	1.0432	1.0477	1.0477	1.0477
80	1.0792	1.0838	1.0845	1.0845	1.0413	1.0468	1.0477	1.0477
81	1.0776	1.0838	1.0845	1.0845	1.0394	1.0468	1.0477	1.0477
82	1.0709	1.0838	1.0845	1.0845	1.0316	1.0468	1.0477	1.0477
83	1.0605	1.0845	1.0845	1.0845	1.0204	1.0477	1.0477	1.0477
84	1.0485	1.0830	1.0830	1.0845	1.0083	1.0459	1.0459	1.0477
85	1.0276	1.0751	1.0751	1.0845	0.9893	1.0365	1.0365	1.0477
86	1.0083	1.0425	1.0425	1.0845	0.9737	1.0026	1.0026	1.0477
87	0.9931	0.9971	0.9971	1.0845	0.9625	0.9654	0.9654	1.0477
88	0.9847	0.9971	0.9971	1.0845	0.9567	0.9654	0.9654	1.0477
89	0.9732	0.9971	0.9971	1.0845	0.9493	0.9654	0.9654	1.0477
90+	0.9606	0.9971	0.9971	1.0845	0.9415	0.9654	0.9654	1.0477

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Table 4-5

Low and High Altitude Adjustment Factors for 10%
Ethanol Blends by Model Year and Type: Evaporative VOC

(100% Use of Blend)

	9.0 + 0.76 psi				11.5 + 0.76 psi			
MY	LDGV	LDGT1	LDGT2	HDGV	LDGV	LDGT1	LDGT2	HDGV
<75	1.2960	1.2960	1.2960	1.2960	1.5370	1.5370	1.5370	1.5370
75	1.2978	1.2960	1.2960	1.2960	1.5432	1.5370	1.5370	1.5370
76	1.2978	1.2960	1.2960	1.2960	1.5432	1.5370	1.5370	1.5370
77	1.2978	1.2960	1.2960	1.2960	1.5432	1.5370	1.5370	1.5370
78	1.2978	1.2960	1.2960	1.2960	1.5432	1.5370	1.5370	1.5370
79	1.2978	1.2960	1.2960	1.2960	1.5432	1.5370	1.5370	1.5370
80	1.2986	1.2963	1.2960	1.2960	1.5458	1.5382	1.5370	1.5370
81	1.2994	1.2963	1.2960	1.2960	1.5483	1.5382	1.5370	1.5370
82	1.3027	1.2963	1.2960	1.2960	1.5589	1.5382	1.5370	1.5370
83	1.3079	1.2960	1.2960	1.2960	1.5743	1.5370	1.5370	1.5370
84	1.3138	1.2967	1.2967	1.2960	1.5907	1.5395	1.5395	1.5370
85	1.3241	1.3006	1.3006	1.2960	1.6167	1.5522	1.5522	1.5370
86	1.3337	1.3168	1.3168	1.2960	1.6379	1.5985	1.5985	1.5370
87	1.3412	1.3392	1.3392	1.2960	1.6531	1.6492	1.6492	1.5370
88	1.3454	1.3392	1.3392	1.2960	1.6610	1.6492	1.6492	1.5370
89	1.3511	1.3392	1.3392	1.2960	1.6712	1.6492	1.6492	1.5370
90+	1.3573	1.3392	1.3392	1.2960	1.6818	1.6492	1.6492	1.5370

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Table 4-6

Low and High Altitude Adjustment Factors for 10%
Ethanol Blends by Model Year and Type: Evaporative VOC

(50% Use of Blend)

	9.0 psi (matched RVP)				11.5 psi (matched RVP)			
MY	LDGV	LDGT1	LDGT2	HDGV	LDGV	LDGT1	LDGT2	HDGV
<75	1.1135	1.1135	1.1135	1.1135	1.1933	1.1933	1.1933	1.1933
75	1.1105	1.1135	1.1135	1.1135	1.1920	1.1933	1.1933	1.1933
76	1.1105	1.1135	1.1135	1.1135	1.1920	1.1933	1.1933	1.1933
77	1.1105	1.1135	1.1135	1.1135	1.1920	1.1933	1.1933	1.1933
78	1.1105	1.1135	1.1135	1.1135	1.1920	1.1933	1.1933	1.1933
79	1.1105	1.1135	1.1135	1.1135	1.1920	1.1933	1.1933	1.1933
80	1.1093	1.1129	1.1135	1.1135	1.1915	1.1930	1.1933	1.1933
81	1.1080	1.1129	1.1135	1.1135	1.1910	1.1930	1.1933	1.1933
82	1.1026	1.1129	1.1135	1.1135	1.1889	1.1930	1.1933	1.1933
83	1.0944	1.1135	1.1135	1.1135	1.1859	1.1933	1.1933	1.1933
84	1.0849	1.1123	1.1123	1.1135	1.1827	1.1928	1.1928	1.1933
85	1.0683	1.1060	1.1060	1.1135	1.1775	1.1903	1.1903	1.1933
86	1.0530	1.0801	1.0801	1.1135	1.1733	1.1811	1.1811	1.1933
87	1.0409	1.0441	1.0441	1.1135	1.1704	1.1711	1.1711	1.1933
88	1.0342	1.0441	1.0441	1.1135	1.1688	1.1711	1.1711	1.1933
89	1.0251	1.0441	1.0441	1.1135	1.1668	1.1711	1.1711	1.1933
90+	1.0151	1.0441	1.0441	1.1135	1.1647	1.1711	1.1711	1.1933

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Table 4-7

Low and High Altitude Adjustment Factors for 10% Ethanol Blends by Model Year and Type: Evaporative VOC

(50% Use of Blend)

	9.0 + 0.76 psi				11.5 + 0.76 psi			
MY	LDGV	LDGT1	LDGT2	HDGV	LDGV	LDGT1	LDGT2	HDGV
<75	1.3454	1.3454	1.3454	1.3454	1.6285	1.6285	1.6285	1.6285
75	1.3485	1.3454	1.3454	1.3454	1.6364	1.6285	1.6285	1.6285
76	1.3485	1.3454	1.3454	1.3454	1.6364	1.6285	1.6285	1.6285
77	1.3485	1.3454	1.3454	1.3454	1.6364	1.6285	1.6285	1.6285
78	1.3485	1.3454	1.3454	1.3454	1.6364	1.6285	1.6285	1.6285
79	1.3485	1.3454	1.3454	1.3454	1.6364	1.6285	1.6285	1.6285
80	1.3497	1.3460	1.3454	1.3454	1.6396	1.6301	1.6285	1.6285
81	1.3510	1.3460	1.3454	1.3454	1.6429	1.6301	1.6285	1.6285
82	1.3565	1.3460	1.3454	1.3454	1.6563	1.6301	1.6285	1.6285
83	1.3650	1.3454	1.3454	1.3454	1.6757	1.6285	1.6285	1.6285
84	1.3747	1.3466	1.3466	1.3454	1.6965	1.6317	1.6317	1.6285
85	1.3917	1.3530	1.3530	1.3454	1.7294	1.6478	1.6478	1.6285
86	1.4074	1.3796	1.3796	1.3454	1.7563	1.7064	1.7064	1.6285
87	1.4197	1.4165	1.4165	1.3454	1.7755	1.7706	1.7706	1.6285
88	1.4266	1.4165	1.4165	1.3454	1.7855	1.7706	1.7706	1.6285
89	1.4359	1.4165	1.4165	1.3454	1.7984	1.7706	1.7706	1.6285
90+	1.4462	1.4165	1.4165	1.3454	1.8118	1.7706	1.7706	1.6285

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Table 4-8

Low and High Altitude Adjustment Factors for 10% Ethanol or 3.7% Oxygen Methanol Blends by Model Year and Type: CO

	Ratio of Blend to Base CO (3.7% O2, Matched RVP)				Ratio of Blend to Base CO (3.7% O2, RVP + 0.76 psi)			
MY	LDGV	LDGT1	LDGT2	HDGV	LDGV	LDGT1	LDGT2	HDGV
<75	0.7550	0.7550	0.7550	0.7550	0.7720	0.7720	0.7720	0.7720
75	0.6718	0.6822	0.7550	0.7550	0.6872	0.6978	0.7720	0.7720
76	0.6666	0.6718	0.7550	0.7550	0.6819	0.6872	0.7720	0.7720
77	0.6666	0.6770	0.7550	0.7550	0.6819	0.6925	0.7720	0.7720
78	0.6614	0.6770	0.7550	0.7550	0.6766	0.6925	0.7720	0.7720
79	0.6614	0.6718	0.6510	0.7550	0.6766	0.6872	0.6660	0.7720
80	0.6630	0.6718	0.6510	0.7550	0.6794	0.6872	0.6660	0.7720
81	0.7482	0.6551	0.6510	0.7550	0.7826	0.6709	0.6660	0.7720
82	0.7415	0.6780	0.6510	0.7550	0.7745	0.6984	0.6660	0.7720
83	0.7536	0.6915	0.6645	0.7550	0.7891	0.7146	0.6822	0.7720
84	0.7779	0.6888	0.6888	0.7550	0.8183	0.7114	0.7114	0.7720
85	0.7779	0.7010	0.7010	0.7550	0.8183	0.7259	0.7259	0.7720
86	0.7766	0.7185	0.7185	0.7550	0.8167	0.7470	0.7470	0.7720
87	0.7847	0.7604	0.7604	0.6780	0.8264	0.7972	0.7972	0.6936
88	0.7847	0.7604	0.7604	0.6780	0.8264	0.7972	0.7972	0.6936
89	0.7847	0.7604	0.7604	0.6780	0.8264	0.7972	0.7972	0.6936
90+	0.7847	0.7604	0.7604	0.6780	0.8264	0.7972	0.7972	0.6936

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Table 4-9

Low and High Altitude Adjustment Factors for 10% Ethanol or 3.7% Oxygen Methanol Blends by Model Year and Type: NOx

Ratio of Blend to Base NOx
(3.7% O2, Any RVP)

MY	LDGV	LDGT1	LDGT2	HDGV
<75	1.0380	1.0380	1.0380	1.0380
75	1.0396	1.0394	1.0380	1.0380
76	1.0397	1.0396	1.0380	1.0380
77	1.0397	1.0395	1.0380	1.0380
78	1.0398	1.0395	1.0380	1.0380
79	1.0398	1.0396	1.0400	1.0380
80	1.0420	1.0396	1.0400	1.0380
81	1.0695	1.0412	1.0400	1.0380
82	1.0675	1.0482	1.0400	1.0380
83	1.0712	1.0523	1.0441	1.0380
84	1.0785	1.0515	1.0515	1.0380
85	1.0785	1.0552	1.0552	1.0380
86	1.0781	1.0605	1.0605	1.0380
87	1.0806	1.0732	1.0732	1.0395
88	1.0806	1.0732	1.0732	1.0395
89	1.0806	1.0732	1.0732	1.0395
90+	1.0806	1.0732	1.0732	1.0395

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Table 4-10

Low and High Altitude Adjustment Factors for 3.7% Oxygen
Methanol Blends by Model Year and Type: Evaporative VOC

(100% Use of Blend)

	9.0 psi (matched RVP)				11.5 psi (matched RVP)			
MY	LDGV	LDGT1	LDGT2	HDGV	LDGV	LDGT1	LDGT2	HDGV
<75	0.9274	0.9274	0.9274	0.9274	0.9040	0.9040	0.9040	0.9040
75	0.9256	0.9274	0.9274	0.9274	0.9018	0.9040	0.9040	0.9040
76	0.9256	0.9274	0.9274	0.9274	0.9018	0.9040	0.9040	0.9040
77	0.9256	0.9274	0.9274	0.9274	0.9018	0.9040	0.9040	0.9040
78	0.9256	0.9274	0.9274	0.9274	0.9018	0.9040	0.9040	0.9040
79	0.9256	0.9274	0.9274	0.9274	0.9018	0.9040	0.9040	0.9040
80	0.9248	0.9270	0.9274	0.9274	0.9010	0.9036	0.9040	0.9040
81	0.9241	0.9270	0.9274	0.9274	0.9001	0.9036	0.9040	0.9040
82	0.9209	0.9270	0.9274	0.9274	0.8964	0.9036	0.9040	0.9040
83	0.9159	0.9274	0.9274	0.9274	0.8911	0.9040	0.9040	0.9040
84	0.9102	0.9267	0.9267	0.9274	0.8854	0.9031	0.9031	0.9040
85	0.9002	0.9229	0.9229	0.9274	0.8765	0.8987	0.8987	0.9040
86	0.8910	0.9073	0.9073	0.9274	0.8691	0.8827	0.8827	0.9040
87	0.8837	0.8857	0.8857	0.9274	0.8639	0.8652	0.8652	0.9040
88	0.8797	0.8857	0.8857	0.9274	0.8611	0.8652	0.8652	0.9040
89	0.8742	0.8857	0.8857	0.9274	0.8576	0.8652	0.8652	0.9040
90+	0.8682	0.8857	0.8857	0.9274	0.8539	0.8652	0.8652	0.9040

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Table 4-11

Low and High Altitude Adjustment Factors for 3.7% Oxygen
Methanol Blends by Model Year and Type: Evaporative VOC

(100% Use of Blend)

	9.0 + 0.76 psi RVP				11.5 + 0.76 psi RVP			
MY	LDGV	LDGT1	LDGT2	HDGV	LDGV	LDGT1	LDGT2	HDGV
<75	1.0950	1.0950	1.0950	1.0950	1.3278	1.3278	1.3278	1.3278
75	1.0990	1.0950	1.0950	1.0950	1.3361	1.3278	1.3278	1.3278
76	1.0990	1.0950	1.0950	1.0950	1.3361	1.3278	1.3278	1.3278
77	1.0990	1.0950	1.0950	1.0950	1.3361	1.3278	1.3278	1.3278
78	1.0990	1.0950	1.0950	1.0950	1.3361	1.3278	1.3278	1.3278
79	1.0990	1.0950	1.0950	1.0950	1.3361	1.3278	1.3278	1.3278
80	1.1007	1.0958	1.0950	1.0950	1.3395	1.3294	1.3278	1.3278
81	1.1024	1.0958	1.0950	1.0950	1.3429	1.3294	1.3278	1.3278
82	1.1095	1.0958	1.0950	1.0950	1.3570	1.3294	1.3278	1.3278
83	1.1205	1.0950	1.0950	1.0950	1.3775	1.3278	1.3278	1.3278
84	1.1332	1.0966	1.0966	1.0950	1.3993	1.3311	1.3311	1.3278
85	1.1553	1.1050	1.1050	1.0950	1.4339	1.3481	1.3481	1.3278
86	1.1758	1.1396	1.1396	1.0950	1.4623	1.4098	1.4098	1.3278
87	1.1919	1.1876	1.1876	1.0950	1.4825	1.4774	1.4774	1.3278
88	1.2008	1.1876	1.1876	1.0950	1.4930	1.4774	1.4774	1.3278
89	1.2130	1.1876	1.1876	1.0950	1.5066	1.4774	1.4774	1.3278
90+	1.2263	1.1876	1.1876	1.0950	1.5207	1.4774	1.4774	1.3278

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Table 4-12

Low and High Altitude Adjustment Factors for 3.7% Oxygen Methanol Blends by Model Year and Type: Evaporative VOC

(50% Use of Blend)

	9.0 psi (matched RVP)				11.5 psi (matched RVP)			
MY	LDGV	LDGT1	LDGT2	HDGV	LDGV	LDGT1	LDGT2	HDGV
<75	1.0202	1.0202	1.0202	1.0202	1.1582	1.1582	1.1582	1.1582
75	1.0208	1.0202	1.0202	1.0202	1.1616	1.1582	1.1582	1.1582
76	1.0208	1.0202	1.0202	1.0202	1.1616	1.1582	1.1582	1.1582
77	1.0208	1.0202	1.0202	1.0202	1.1616	1.1582	1.1582	1.1582
78	1.0208	1.0202	1.0202	1.0202	1.1616	1.1582	1.1582	1.1582
79	1.0208	1.0202	1.0202	1.0202	1.1616	1.1582	1.1582	1.1582
80	1.0210	1.0203	1.0202	1.0202	1.1630	1.1589	1.1582	1.1582
81	1.0213	1.0203	1.0202	1.0202	1.1644	1.1589	1.1582	1.1582
82	1.0223	1.0203	1.0202	1.0202	1.1702	1.1589	1.1582	1.1582
83	1.0239	1.0202	1.0202	1.0202	1.1786	1.1582	1.1582	1.1582
84	1.0258	1.0204	1.0204	1.0202	1.1876	1.1596	1.1596	1.1582
85	1.0291	1.0216	1.0216	1.0202	1.2018	1.1666	1.1666	1.1582
86	1.0321	1.0267	1.0267	1.0202	1.2135	1.1919	1.1919	1.1582
87	1.0345	1.0338	1.0338	1.0202	1.2218	1.2196	1.2196	1.1582
88	1.0358	1.0338	1.0338	1.0202	1.2261	1.2196	1.2196	1.1582
89	1.0376	1.0338	1.0338	1.0202	1.2317	1.2196	1.2196	1.1582
90+	1.0395	1.0338	1.0338	1.0202	1.2375	1.2196	1.2196	1.1582

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Table 4-13

Low and High Altitude Adjustment Factors for 3.7% Oxygen Methanol Blends by Model Year and Type: Evaporative VOC

(50% Use of Blend)

	9.0 + 0.76 psi RVP				11.5 + 0.76 psi RVP			
MY	LDGV	LDGT1	LDGT2	HDGV	LDGV	LDGT1	LDGT2	HDGV
<75	1.2449	1.2449	1.2449	1.2449	1.6048	1.6048	1.6048	1.6048
75	1.2525	1.2449	1.2449	1.2449	1.6217	1.6048	1.6048	1.6048
76	1.2525	1.2449	1.2449	1.2449	1.6217	1.6048	1.6048	1.6048
77	1.2525	1.2449	1.2449	1.2449	1.6217	1.6048	1.6048	1.6048
78	1.2525	1.2449	1.2449	1.2449	1.6217	1.6048	1.6048	1.6048
79	1.2525	1.2449	1.2449	1.2449	1.6217	1.6048	1.6048	1.6048
80	1.2557	1.2464	1.2449	1.2449	1.6287	1.6081	1.6048	1.6048
81	1.2589	1.2464	1.2449	1.2449	1.6357	1.6081	1.6048	1.6048
82	1.2726	1.2464	1.2449	1.2449	1.6645	1.6081	1.6048	1.6048
83	1.2936	1.2449	1.2449	1.2449	1.7064	1.6048	1.6048	1.6048
84	1.3178	1.2479	1.2479	1.2449	1.7510	1.6115	1.6115	1.6048
85	1.3601	1.2639	1.2639	1.2449	1.8217	1.6463	1.6463	1.6048
86	1.3993	1.3300	1.3300	1.2449	1.8797	1.7724	1.7724	1.6048
87	1.4300	1.4220	1.4220	1.2449	1.9210	1.9105	1.9105	1.6048
88	1.4471	1.4220	1.4220	1.2449	1.9425	1.9105	1.9105	1.6048
89	1.4704	1.4220	1.4220	1.2449	1.9703	1.9105	1.9105	1.6048
90+	1.4959	1.4220	1.4220	1.2449	1.9991	1.9105	1.9105	1.6048

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Table 4-14

Low and High Altitude Adjustment Factors for
11% MTBE Blends by Model Year and Type: Exhaust VOC

Ratio of Blend to Base Exh VOC
(2.0% O2, Matched RVP)

MY	LDGV	LDGT1	LDGT2	HDGV
<75	0.9703	0.9703	0.9703	0.9703
75	0.9266	0.9321	0.9703	0.9703
76	0.9239	0.9266	0.9703	0.9703
77	0.9239	0.9293	0.9703	0.9703
78	0.9211	0.9293	0.9703	0.9703
79	0.9211	0.9266	0.9157	0.9703
80	0.9212	0.9266	0.9157	0.9703
81	0.9565	0.9174	0.9157	0.9703
82	0.9537	0.9270	0.9157	0.9703
83	0.9588	0.9327	0.9214	0.9703
84	0.9690	0.9316	0.9316	0.9703
85	0.9690	0.9367	0.9367	0.9703
86	0.9685	0.9441	0.9441	0.9703
87	0.9719	0.9616	0.9616	0.9299
88	0.9719	0.9616	0.9616	0.9299
89	0.9719	0.9616	0.9616	0.9299
90+	0.9719	0.9616	0.9616	0.9299

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Table 4-15

Low and High Altitude Adjustment Factors for
11% MTBE Blends by Model Year and Type: Exhaust CO

Ratio of Blend to Base CO
(2.0% O2, Matched RVP)

MY	LDGV	LDGT1	LDGT2	HDGV
<75	0.8676	0.8676	0.8676	0.8676
75	0.8226	0.8282	0.8676	0.8676
76	0.8198	0.8226	0.8676	0.8676
77	0.8198	0.8254	0.8676	0.8676
78	0.8170	0.8254	0.8676	0.8676
79	0.8170	0.8226	0.8114	0.8676
80	0.8178	0.8226	0.8114	0.8676
81	0.8639	0.8135	0.8114	0.8676
82	0.8602	0.8259	0.8114	0.8676
83	0.8668	0.8332	0.8186	0.8676
84	0.8799	0.8318	0.8318	0.8676
85	0.8799	0.8384	0.8384	0.8676
86	0.8792	0.8478	0.8478	0.8676
87	0.8836	0.8705	0.8705	0.8260
88	0.8836	0.8705	0.8705	0.8260
89	0.8836	0.8705	0.8705	0.8260
90+	0.8836	0.8705	0.8705	0.8260

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Table 4-16

Low and High Altitude Adjustment Factors for
11% MTBE Blends by Model Year and Type: Exhaust NOx

Ratio of Blend to Base NOx
(2.0% O2, Any RVP)

MY	LDGV	LDGT1	LDGT2	HDGV
<75	1.0205	1.0205	1.0205	1.0205
75	1.0214	1.0213	1.0205	1.0205
76	1.0215	1.0214	1.0205	1.0205
77	1.0215	1.0214	1.0205	1.0205
78	1.0215	1.0214	1.0205	1.0205
79	1.0215	1.0214	1.0216	1.0205
80	1.0227	1.0214	1.0216	1.0205
81	1.0376	1.0223	1.0216	1.0205
82	1.0365	1.0261	1.0216	1.0205
83	1.0385	1.0283	1.0238	1.0205
84	1.0425	1.0278	1.0278	1.0205
85	1.0425	1.0298	1.0298	1.0205
86	1.0422	1.0327	1.0327	1.0205
87	1.0436	1.0396	1.0396	1.0213
88	1.0436	1.0396	1.0396	1.0213
89	1.0436	1.0396	1.0396	1.0213
90+	1.0436	1.0396	1.0396	1.0213

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Table 4-17

Low and High Altitude Adjustment Factors for
11% MTBE Blends by Model Year and Type: Evaporative VOC

	9.0 psi (matched RVP)				11.5 psi (matched RVP)			
MY	LDGV	LDGT1	LDGT2	HDGV	LDGV	LDGT1	LDGT2	HDGV
<75	1.0993	1.0993	1.0993	1.0993	1.0828	1.0828	1.0828	1.0828
75	1.0969	1.0993	1.0993	1.0993	1.0797	1.0828	1.0828	1.0828
76	1.0969	1.0993	1.0993	1.0993	1.0797	1.0828	1.0828	1.0828
77	1.0969	1.0993	1.0993	1.0993	1.0797	1.0828	1.0828	1.0828
78	1.0969	1.0993	1.0993	1.0993	1.0797	1.0828	1.0828	1.0828
79	1.0969	1.0993	1.0993	1.0993	1.0797	1.0828	1.0828	1.0828
80	1.0958	1.0989	1.0993	1.0993	1.0785	1.0822	1.0828	1.0828
81	1.0948	1.0989	1.0993	1.0993	1.0772	1.0822	1.0828	1.0828
82	1.0903	1.0989	1.0993	1.0993	1.0720	1.0822	1.0828	1.0828
83	1.0834	1.0993	1.0993	1.0993	1.0644	1.0828	1.0828	1.0828
84	1.0755	1.0984	1.0984	1.0993	1.0563	1.0816	1.0816	1.0828
85	1.0616	1.0931	1.0931	1.0993	1.0435	1.0753	1.0753	1.0828
86	1.0488	1.0715	1.0715	1.0993	1.0330	1.0524	1.0524	1.0828
87	1.0387	1.0413	1.0413	1.0993	1.0255	1.0274	1.0274	1.0828
88	1.0331	1.0413	1.0413	1.0993	1.0216	1.0274	1.0274	1.0828
89	1.0255	1.0413	1.0413	1.0993	1.0166	1.0274	1.0274	1.0828
90+	1.0171	1.0413	1.0413	1.0993	1.0114	1.0274	1.0274	1.0828

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Table 4-18

Adjustments for Emission Factors Associated with Alternate Fuels CNG, Methanol, and Flexible Fueled 1990+ Vehicles*

		Methanol Vehicles		
	CNG Vehicles	Just Meeting EPA Emission Standard	Emissions Well Below EPA Standard	Intermediate Emission Level
HC Exhaust	0.60	0.66	0.17	0.32
CO	0.50	-		
NOx	1.40	-		
HC Evap**	0.0	0.68	0.15	0.52
	0.0	0.29	0.07	0.22

* Reductions may be claimed only for the periods during which alternate fuels are used. Factors are for LDGV, LDGT1, LDGT2, and HDGV.

** The first row is for the adjustment factor for comparing to a 9 psi RVP gasoline fuel while the second is row for comparison to a 11.5 psi RVP gasoline.

Appendix A

Formula for Quadratic Interpolation Based on Different Blend Market Share

Appendix A

Formula for Quadratic Interpolation Based on Different Blend Market Share

Use a quadratic equation of the form:

(1) $y = Ax^2 + Bx + C$

where y = Evaporative VOC adjustment factor (for market share other than 0, 50 or 100%),
x = Market share of fuel of interest (0 - 100%),
A, B, C = Coefficients to be determined,

to fit a curve to the three points (0, 50, and 100% market share) given in the tables in Section 4 for the blend of interest. This means finding the coefficients A, B, and C for the model year, vehicle type, and blend of interest. Once these coefficients are found, the market share of interest (x) for that blend is put into the equation and the equation is solved for y, which is the adjustment factor to use for that specific model year and vehicle type (e.g., MY 1985, LDGV). This same procedure then needs to be followed for each model year and each vehicle type.

Determination of Coefficients A, B, and C

These equations provide an example of how to determine the coefficients for a case with a 9.0 psi ethanol blend for the 1985 model year, LDGV, which uses adjustment values (x) from Tables 4-4 and 4-6. In general, values for x for the 50% market share cases will come from Tables 4-6 or 4-7 for ethanol blends or Tables 4-12 or 4-13 for methanol/cosolvent blends. For the 100% market share cases values for x will come from Tables 4-4 or 4-5 for ethanol blends or Tables 4-10 or 4-11 for methanol/cosolvent blends.

As shown in equation (2) below, the adjustment factor for 0% blend market share will always be 1.0, and therefore, the coefficient, C, will always be 1.0.

(2) 0% market share: $1.00 = A(0)^2 + B(0) + C$
(3) 50% market share: $0.9792 = A(50)^2 + B(50) + C$
(4) 100% market share: $0.8994 = A(100)^2 + B(100) + C$

To determine A and B, equations (3) and (4) are used, which means solving two equations with two unknowns (since C is already known to be 1.0). These can easily be solved by multiplying each term of equation (3) by 2.0 and subtracting equation (4) from it, as shown in equations (3a), (4a), and (5).

(3a) $1.9584 = A(5{,}000) + B(100) + 2.0$
(4a) $- \quad 0.8994 = A(10{,}000) + B(100) + 1.0$

---

(5) $1.0590 = -A(5{,}000) + 1.0$

(5a) $A = -1.18 \times 10^{-5}$

The coefficient, B, can then be determined by substituting the value of A from equation (5a) into equation (3a) and solving for B. This is shown in equations (6) and (6a).

(6) $1.9584 = (-1.18 \times 10^{-5})(5{,}000) + B(100) + 2.0$

(6a) $B = 1.74 \times 10^{-4}$

Determination of Adjustment Factor

Using the values for A, B, and C determined as shown for a given model year, vehicle type, and blend, the adjustment factor, y, for any specific market share can be determined. To continue with the same example using an ethanol blend market share of 25%:

(7) $y = (-1.18 \times 10^{-5})(25)^2 + (1.74 \times 10^{-4})(25) + 1.0$

(7a) $y = 0.9970$

Please note that this just gives the evaporative adjustment factor for model year 1985, LDGV, with a 25% market share of a 10% ethanol blend (and 75% market share of oxygen-free gasoline and/or gasoline-MTBE blends). The same type of calculations would need to be done for each model year and vehicle type to obtain factors for use with the modified MOBILE3 output by model year.

Appendix B

Commingling Calculations with Nonoxygenated Gasoline and Two Blends in the Market Simultaneously

Appendix B

Commingling Calculations with Nonoxygenated Gasoline and Two Blends in the Market Simultaneously

Tables 4-3 through 4-17 can be used to calculate emission impacts for any two of the various fuels including gasoline, ethanol blends, MTBE blends, methanol blends or even all three oxygenated blends. These tables cannot be directly used to calculate emission effects of a market situation consisting of two oxygenated blends with gasoline. The following methodology must be used instead. Either an ethanol blend or a methanol blend can be present (along with MTBE and nonoxygenated gasoline) but not both for this methodology to work.

The market place contains the following fuels.

m% = ethanol blends

n% = methanol blends

p% = MTBE blends

q% = gasoline

where m% + n% + p% + q% = 100% with either m or n being zero.

It is reasonably assumed that the RVP increase due to commingling has a negligible effect on exhaust emissions of HC and CO. Thus, one uses the appropriate factors for exhaust emissions (linearly adjusted based on market share) from Tables 4-3, 4-8, and 4-9 for HC, CO, and NOx for ethanol or methanol blends. For MTBE blends Tables 4-14, 4-15, 4-16 are used.

The evaporative emission factor adjustment for the multi-blend case is more complicated. Basically, the strength of the commingling effect of the alcohol must be reduced to account for the fact that commingling with MTBE blends has no non-linear effects. The overall equation for this calculation is shown below for an ethanol blend.

E = (m/100)(100% gasohol case) + (p/100)(100% MTBE case) +

(q/[p + q])(m% gasohol case -

[m/100][100% gasohol case])

where m and p are as given above, the 100% gasohol case is the adjustment factor given by Table 4-4 and the m% gasohol case adjustment factor is calculated by the quadratic methodology described in Section 4 and Appendix A. And, E is the new adjustment factor for evaporative emissions for a given model year.

The same general methodology can be used with methanol and MTBE blends in the market place with gasoline with n% being the methanol fraction and the 100% gasohol case coming from Table 4-10.

If both ethanol and methanol blends are in the market place along with MTBE and gasoline, please contact EPA for appropriate guidance.

Appendix C

Examples of Calculations

Appendix C

Examples of Calculations

The following examples demonstrate the procedures described in Appendix D.

Example 1 - Calculate the emission changes from 100% use of splash blended gasohol with a 12.26 psi average RVP level in the calendar year 1990.

For this example, some of the work has already been done. Tables 4-3, 4-5, 4-8, and 4-9 show adjustments to the emission factors, as calculated for each vehicle type and model year combination for the case of 100% market penetration of a 10% ethanol blend with RVP of 12.26 psi and no volatility adjustment (base gasoline RVP is 11.5 psi.)

The following pages show the special MOBILE3 printout, which lists emission factors for exhaust HC, CO, NOx, and evaporative HC for each model year and vehicle class. MOBILE3 has already weighted each of these emission factors by the travel fraction of the model year within the vehicle class. To perform the hand calculations, the appropriate adjustment factors are chosen from the tables in Section 4 (i.e., Tables 4-3, 4-5, 4-8, and 4-9) and written to the left of the emission factors on the MOBILE3 printout. The multiple of each emission factor and the appropriate adjustment factor is written to the left of the adjustment factor. For each column these multiples are added together, and the sum is written at the bottom of the column. This value is the adjusted emission factor for all vehicles in that vehicle class. This process must be repeated for sixteen combinations of vehicle class and pollutant. The evaporative and exhaust HC are combined to yield a total HC emission factor for each vehicle type.

The adjusted emission factors must now be weighted and recombined with the emission factors of the vehicle classes which were not adjusted (diesels and motorcycles) to form the composite emission factor for the fleet. The first page of the MOBILE3 output lists the unadjusted emission factors by vehicle class and the travel fraction weights ("Composite emission Factors" and "VMT Mix"). To find the adjusted emission factor of a given pollutant for the whole fleet, multiply the adjusted emission factor (or unadjusted emission factor, in the case of motorcycles and diesel fueled vehicles) for each vehicle type by the VMT mix for that type, and add the results for all types together.

Four pages which follow are photocopies of the special MOBILE3 output. The results show a 15% increase in non-methane HC (from 2.54 to 2.92 g/mile), a 25% reduction in CO (from 18.19 to 13.71 g/mile), and 4% increase in NOx.

Example 2 - Calculate the emission changes for the year 2005 which would result from substitution of methanol fueled vehicles for 30% of new sales of gasoline vehicles of all classes beginning in the 1997 model year. These methanol fueled vehicles are designed to have emissions well below the EPA standards.

Section 3.2.2.3 and Table 4-18 of the report indicate HC adjustment factors of 0.17 and 0.07 for exhaust and evaporative emissions for methanol fueled vehicles with emissions well below the standards. These adjustment factors are applied as described above but for only 30% of the gasoline fleet beginning starting with the 1997 model year; the emission level for the remaining 70% of the gasoline fleet remains unchanged. The net adjustments are therefore 0.751 for exhaust.

For evaporative emissions, the emissions of the fleet expected to exist without methanol substitution should be compared with those of the fleet which would exist if 30% of all gasoline fueled vehicles were replaced by dedicated methanol fueled vehicles. The actual percentages of carbureted and fuel injected vehicles for any model year are listed in Table 4-1.

For this example, the fraction of the original fleet for any model year that is composed of carbureted vehicles should be denoted as Y while that fraction for fuel injected vehicles would be Z. With the 30% methanol fueled vehicle substitution, the remaining gasoline carbureted vehicles would be 0.7 x Y% while it would be 0.3 x Z% for the fuel injected vehicles. Assuming an 11.5 psi RVP gasoline, the reference emission levels for these vehicles from Table 4-2 are 0.711 and 0.516 g/mile for carbureted and fuel injected vehicles respectively. Assuming the methanol fueled vehicles have 93% lower emissions than the fuel injected vehicles, their reference emission levels would be 0.036 g/mile.

The ratio of the emissions of the two fleets for model years 1997 and beyond would be as follows.

$$\frac{(0.7xY\%) \times 0.711 \text{ g/mi} + (0.7xZ\%) \times 0.516 \text{ g/mi} + 30\% \times 0.036 \text{ g/mi}}{Y\% \times 0.711 \text{ g/mi} + Z\% \times 0.516 \text{ g/mi}}$$

This ratio of the reference emission levels can be applied to the actual emission levels in the MOBILE3 output as the adjustment factor.

for LDGV's, $Y = 0.11$, $Z = 0.89$

$$\frac{0.7 \times 0.11 \times 0.711 + 0.7 \times 0.89 \times 0.516 + 0.3 \times 0.036}{0.11 \times 0.711 + 0.89 \times 0.516} = \frac{0.387}{0.537} = 0.721$$

for LDGT1 and 2, $Y = 0.27$, $Z = 0.73$

$$\frac{0.7 \times 0.27 \times 0.711 + 0.7 \times 0.73 \times 0.516 + 0.3 \times 0.036}{0.27 \times 0.711 + 0.73 \times 0.516} = \frac{0.409}{0.569} = 0.719$$

for HDGV, $Y = 1.0$, $Z = 0$

$$\frac{0.7 \times 1 \times 0.711 + 0.3 \times 0.036}{0.711} = 0.715$$

The rest of the calculations are done as described for the first example. These results show a 16% reduction in 2005 non-methane HC emissions (from 2.91 to 2.54 g/mile) due to introduction of these methanol-fueled vehicles.

Calculation example; default fleet with I/M program

I/M program selected:

Start year (January 1):	1983
Pre-1981 MVR stringency rate:	20%
Mechanic training program?:	No
First model year covered:	1951
Last model year covered:	2020
Vehicle types covered:	LDGV
1981 & later MVR test type:	Idle
1981 & later MVR test cutpoints:	1.2% ICO / 220 ppm IHC

Non-methane HC emission factors include evaporative HC emission factors.

Cal. Year: 1990 I/M Program: Yes Ambient Temp: 75.0 (F) Region: Low
Anti-tam. Program: No Operating Mode: 20.6 / 27.3 / 20.6 Altitude: 500. Ft.

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:	0.635	0.115	0.086		0.041	0.046	0.021	0.049	0.007	
Composite Emission Factors (Gm/Mile)										
Non-Meth HC:	1.76	4.27	4.85	4.52	6.68	0.39	0.61	3.40	5.77	2.54
*Evap HC:	0.72	1.14	1.40	1.25	3.58	0.0	0.0	0.0	2.26	----
Exhaust CO:	11.77	34.84	37.39	35.93	66.48	1.32	1.53	11.11	19.73	18.19
Exhaust NOX:	1.49	2.80	3.01	2.89	5.36	1.10	1.28	15.22	0.85	2.57

Adjusted Emission Factor (where affected)

	LDGV	LDGT1	LDGT2	HDGV	All Veh
Non-Meth HC:	2.11	4.60	5.34	8.40	2.91
CO:	8.91	25.11	27.40	50.44	13.71
NOx:	1.59	2.94	3.16	5.57	2.67

* Adjusted emission factors are calculated on the following pages

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		Model Year	LDGV			LDGT1			LDGT2			HDGV		
Exhaust	HC:	1990	0.006	.9748	.006	0.024	.9530	.023	0.025	.9530	.024	0.0	.8818	0
		1989	0.038	.9748	.037	0.109	.9530	.104	0.112	.9530	.107	0.324	.8818	.285
		1988	0.051	.9748	.050	0.121	.9530	.115	0.125	.9530	.119	0.304	.8818	.268
		1987	0.059	.9748	.058	0.128	.9530	.122	0.133	.9530	.127	0.273	.8818	.241
		1986	0.062	.9675	.060	0.150	.9155	.137	0.155	.9155	.142	0.239	.9580	.229
		1985	0.063	.9687	.061	0.150	.8998	.135	0.155	.8998	.139	0.214		.205
		1984	0.061	.9687	.059	0.194	.8889	.172	0.199	.8889	.177	0.260		.249
		1983	0.056	.9470	.053	0.255	.8713	.227	0.270	.8671	.234	0.210		.201
		1982	0.052	.9361	.049	0.247	.8792	.217	0.260	.8550	.222	0.170		.163
		1981	0.048	.9421	.045	0.237	.8586	.203	0.242	.8550	.207	0.134		.128
		1980	0.056	.8662	.049	0.249	.8756	.218	0.265	.8550	.227	0.120		.115
		1979	0.109	.8653	.094	0.224	.8756	.196	0.237	.8550	.203	0.095		.091
		1978	0.096	.8653	.083	0.225	.8808	.198	0.268	.9580	.267	0.129		.124
		1977	0.080	.8704	.070	0.195	.8808	.172	0.227		.217	0.113		.108
		1976	0.063	.8704	.055	0.169	.8756	.148	0.189		.181	0.093		.089
		1975	0.045	.8756	.039	0.138	.8859	.122	0.154		.148	0.071		.068
		1974	0.032	.9580	.031	0.089	.9580	.085	0.124		.119	0.056		.054
		1973	0.022	.9580	.021	0.070	.9580	.067	0.112		.107	0.057		.055
		1972	0.015	.9580	.014	0.051	.9580	.049	0.084		.080	0.042		.040
		1971	0.028	.9580	.027	0.109	.9580	.104	0.117	.9580	.112	0.194	.9580	.186
	SUM:		1.043		.961	3.132		2.814	3.453		3.149	3.097		2.899
Evaporative	HC:	1990	0.017	1.6818	.029	0.020	1.6492	.033	0.018	1.6492	.030	0.0	1.5370	
		1989	0.069	1.6712	.115	0.083	1.6492	.137	0.072	1.6492	.119	0.440		
		1988	0.063	1.6610	.105	0.077	1.6492	.127	0.068	1.6492	.112	0.349		
		1987	0.057	1.6531	.094	0.078	1.6492	.129	0.069	1.6492	.114	0.276		
		1986	0.056	1.6379	.092	0.077	1.5985	.123	0.068	1.5985	.109	0.219		
		1985	0.051	1.6167	.082	0.076	1.5522	.118	0.066	1.5522	.102	0.171		
		1984	0.049	1.5907	.078	0.074	1.5395	.114	0.064	1.5395	.099	0.477		
		1983	0.045	1.5743	.071	0.071	1.5370	.109	0.061	1.5370	.094	0.370		
		1982	0.041	1.5589	.064	0.065	1.5387	.100	0.056	1.5370	.086	0.285		
		1981	0.036	1.5483	.056	0.058	1.5362	.089	0.050	1.5370	.077	0.218		
		1980	0.033	1.5459	.051	0.050	1.5382	.077	0.044	1.5370	.068	0.172		
		1979	0.028	1.5432	.043	0.045	1.5370	.069	0.039	1.5370	.060	0.132		
		1978	0.023	1.5432	.035	0.039	1.5370	.060	0.163	1.5370	.251	0.103		
		1977	0.047	1.5432	.073	0.076	1.5370	.117	0.136	1.5370	.209	0.078		
		1976	0.035	1.5432	.054	0.063	1.5370	.097	0.112	1.5370	.172	0.063		
		1975	0.025	1.5432	.039	0.051	1.5370	.078	0.091	1.5370	.140	0.048		
		1974	0.015	1.5370	.023	0.041	1.5370	.063	0.072	1.5370	.111	0.038		
		1973	0.010	1.5370	.015	0.032	1.5370	.049	0.056	1.5370	.086	0.029		
		1972	0.007	1.5370	.011	0.024	1.5370	.037	0.041	1.5370	.063	0.021		
		1971	0.012	1.5370	.018	0.039	1.5370	.060	0.053	1.5370	.081	0.091	1.5370	
	SUM:		0.720		1.148	1.139		1.786	1.397		2.188	3.580		5.502
TOTAL	SUM:		1.763		2.109	4.271		4.600	4.850		5.337	6.677		8.401

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	Model Year	LDGV			LDGT1			LDGT2			HDGV		
CO:	1990	0.067	.9264	.055	0.287	.7972	.229	0.295	.7972	.235	0.0	.6936	-
	1989	0.446	.8264	.369	1.307	.7972	1.042	1.347	.7972	1.074	4.285	.6936	2.972
	1988	0.648	.8264	.536	1.476	.7972	1.177	1.523	.7972	1.204	3.747	.6936	2.599
	1987	0.764	.8264	.632	1.586	.7972	1.264	1.634	.7972	1.303	3.202	.6936	2.221
	1986	0.829	.8167	.677	1.675	.7470	1.251	1.725	.7470	1.288	3.882	.7720	2.997
	1985	0.845	.8183	.691	1.641	.7259	1.191	1.685	.7259	1.223	3.725		2.876
	1984	0.822	.8183	.673	1.975	.7114	1.405	2.026	.7114	1.441	8.772		6.772
	1983	0.722	.7891	.570	2.529	.7146	1.907	2.655	.6822	1.811	7.004		5.407
	1982	0.658	.7745	.510	2.402	.6984	1.677	2.511	.6660	1.672	5.628		4.345
	1981	0.646	.7836	.506	2.272	.6709	1.524	2.311	.6660	1.539	4.427		3.418
	1980	0.528	.6794	.359	2.809	.6872	1.930	2.939	.6660	1.957	3.828		2.955
	1979	1.110	.6766	.751	2.516	.6872	1.729	2.619	.6660	1.744	3.007		2.321
	1978	0.978	.6766	.662	2.561	.6925	1.773	3.039	.7720	2.346	2.702		2.086
	1977	0.807	.6819	.551	2.214	.6925	1.533	2.582		1.994	2.346		1.811
	1976	0.638	.6819	.435	1.916	.6872	1.317	2.159		1.667	1.939		1.497
	1975	0.461	.6872	.317	1.565	.6978	1.092	1.773		1.369	1.482		1.144
	1974	0.284	.7720	.219	1.255	.7720	0.969	1.425		1.100	1.176		0.909
	1973	0.195	.7720	.151	0.986	.7720	0.761	1.124		.868	1.032		0.797
	1972	0.131	.7720	.101	0.716	.7720	0.553	0.840		.649	0.772		0.596
	1971	0.184	.7720	.142	1.151	.7720	0.899	1.176	.7720	.909	3.524	.7720	2.720
				8.905			25.114			27.401			50.441
SUM:		11.766			34.838			37.387			66.479		

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	Model Year	LDGV			LDGT1			LDGT2			HDGV		
NOX:	1990	0.021	1.0806	.022	0.037	1.0732	.039	0.037	1.0732	.040	0.0	1.0395	0
	1989	0.093	1.0806	.101	0.154	1.0732	.165	0.158	1.0732	.170	1.114	1.0395	1.158
	1988	0.104	1.0806	.112	0.160	1.0732	.171	0.164	1.0732	.176	0.917	1.0395	.953
	1987	0.111	1.0806	.119	0.162	1.0732	.173	0.166	1.0732	.179	0.749	1.0395	.778
	1986	0.108	1.0791	.117	0.237	1.0605	.251	0.242	1.0605	.257	0.523	1.0380	.543
	1985	0.107	1.0785	.116	0.225	1.0552	.238	0.230	1.0552	.242	0.402		.418
	1984	0.103	1.0785	.111	0.245	1.0515	.257	0.250	1.0515	.262	0.331		.344
	1983	0.093	1.0712	.100	0.231	1.0523	.243	0.232	1.0441	.242	0.258		.269
	1982	0.090	1.0675	.096	0.213	1.0482	.223	0.215	1.0400	.223	0.203		.211
	1981	0.078	1.0695	.084	0.195	1.0412	.203	0.197	1.0400	.205	0.157		.163
	1980	0.118	1.0419	.123	0.175	1.0396	.182	0.176	1.0400	.183	0.132		.137
	1979	0.114	1.0398	.118	0.155	1.0396	.161	0.155	1.0400	.161	0.102		.106
	1978	0.097	1.0398	.100	0.133	1.0395	.138	0.169	1.0380	.175	0.084		.087
	1977	0.078	1.0397	.081	0.113	1.0395	.118	0.142		.147	0.072		.075
	1976	0.059	1.0397	.061	0.095	1.0396	.098	0.117		.122	0.059		.061
	1975	0.042	1.0396	.044	0.078	1.0394	.081	0.096		.099	0.045		.046
	1974	0.026	1.0380	.027	0.058	1.0380	.060	0.076		.079	0.035		.037
	1973	0.018	1.0380	.019	0.045	1.0380	.046	0.071		.073	0.035		.036
	1972	0.015	1.0380	.015	0.036	1.0380	.038	0.051		.053	0.026		.027
	1971	0.018	1.0380	.019	0.050	1.0382	.052	0.071	1.0380	.073	0.116	1.0380	.121
SUM:		1.493		1.586	2.796		2.941	3.015		3.164	5.361		5.569

Comment: Current output unit numbers are IOUREP=6 IOUERR=6 IOUASK=2

Calculation example; default fleet with I/M program

I/M program selected:

Start year (January 1):	1983
Pre-1981 MVR stringency rate:	20%
Mechanic training program?:	No
First model year covered:	1951
Last model year covered:	2020
Vehicle types covered:	LDGV
1981 & later MVR test type:	Idle
1981 & later MVR test cutpoints:	1.2% ICO / 220 ppm IHC

Non-methane HC emission factors include evaporative HC emission factors.

Cal. Year: 2005 I/M Program: Yes Ambient Temp: 75.0 (F) Region: Low
Anti-tam. Program: No Operating Mode: 20.5 / 27.3 / 20.6 Altitude: 500. Ft.

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:	0.605	0.091	0.089		0.041	0.078	0.046	0.044	0.007	
Composite Emission Factors (Gm/Mile)										
Non-Meth HC:	1.18	2.36	2.30	2.33	4.17	0.42	0.70	2.64	5.77	1.53
*Evap HC:	0.52	0.72	0.64	0.68	2.07	0.0	0.0	0.0	2.26	----
Exhaust CO:	8.77	20.40	20.57	20.48	24.49	1.37	1.61	9.93	19.71	10.74
Exhaust NOX:	1.29	1.93	1.95	1.94	5.41	1.03	1.16	11.86	0.85	2.01
Adjusted Emission Factors (where affected)										
Non-Meth HC:	0.96	1.95	1.91		3.25					1.28

*Adjusted emission factors are calculated on the following pages

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		Model Year	LDGV		LDGT1		LDGT2		HDGV	
Exhaust	HC:	2005	0.007		0.029		0.029		0.0	
		2004	0.038		0.125		0.128		0.307	
		2003	0.050		0.133		0.138		0.288	
		2002	0.057		0.136		0.141		0.258	
		2001	0.061		0.135		0.139		0.225	
		2000	0.061		0.131		0.135		0.190	
		1999	0.058		0.125		0.128		0.160	
		1998	0.054		0.117		0.119		0.133	
		1997	0.050	.751 .327	0.108	.751 .790	0.109	.751 .801	0.108	.751 1.253
		1996	0.045		0.098		0.099		0.087	
		1995	0.040		0.086		0.087		0.072	
		1994	0.034		0.078		0.078		0.057	
		1993	0.029		0.069		0.069		0.046	
		1992	0.024		0.060		0.060		0.036	
		1991	0.019		0.052		0.051		0.030	
		1990	0.013		0.044		0.043		0.024	
		1989	0.009		0.037		0.036		0.019	
		1988	0.006		0.030		0.030		0.015	
		1987	0.005		0.024		0.023		0.011	
		1986	0.005	1. .229	0.019	1. .587	0.018	1. .594	0.037	1. .434
	SUM:		0.664	.556	1.635	1.377	1.660	1.395	2.104	1.687
Evaporative	HC:	2005	0.018		0.024		0.021		0.0	
		2004	0.068		0.090		0.079		0.440	
		2003	0.062		0.081		0.072		0.349	
		2002	0.056		0.073		0.065		0.276	
		2001	0.050		0.065		0.058		0.219	
		2000	0.044		0.058		0.052		0.171	
		1999	0.039		0.051		0.046		0.135	
		1998	0.034		0.045		0.040		0.106	
		1997	0.030	.721 .289	0.040	.719 .380	0.036	.719 .337	0.083	.715 1.272
		1996	0.026		0.035		0.031		0.064	
		1995	0.022		0.029		0.026		0.051	
		1994	0.018		0.026		0.023		0.039	
		1993	0.015		0.022		0.020		0.031	
		1992	0.012		0.019		0.017		0.023	
		1991	0.009		0.016		0.014		0.019	
		1990	0.006		0.013		0.012		0.015	
		1989	0.004		0.011		0.010		0.012	
		1988	0.003		0.009		0.008		0.009	
		1987	0.002		0.008		0.007		0.007	
		1986	0.002	1. .119	0.008	1. .196	0.006	1. .174	0.020	1. .290
	SUM:		0.518	.408	0.724	.576	0.640	.511	2.068	1.562
TOTAL	SUM:		1.182	.964	2.360	1.953	2.301	1.906	4.172	3.249

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No Effect

	Model Year	LDGV	LDGT1	LDGT2	HDGV
CO:	2005	0.070	0.341	0.349	0.0
	2004	0.460	1.500	1.544	4.074
	2003	0.658	1.628	1.677	3.571
	2002	0.766	1.682	1.731	3.056
	2001	0.816	1.680	1.724	2.585
	2000	0.825	1.637	1.673	2.127
	1999	0.783	1.563	1.590	1.761
	1998	0.724	1.467	1.486	1.434
	1997	0.661	1.357	1.369	1.153
	1996	0.594	1.239	1.243	0.926
	1995	0.524	1.095	1.092	0.753
	1994	0.454	0.986	0.979	0.596
	1993	0.383	0.877	0.866	0.483
	1992	0.313	0.768	0.755	0.373
	1991	0.244	0.662	0.647	0.310
	1990	0.176	0.560	0.544	0.241
	1989	0.112	0.472	0.457	0.192
	1988	0.080	0.389	0.374	0.149
	1987	0.059	0.306	0.293	0.112
	1986	0.064	0.187	0.179	0.599
SUM:		8.768	20.396	20.571	24.494

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Jan 1, 2005

No Effect

	Model Year	LDGV	LDGT1	LDGT2	HDGV
NOX:	2005	0.022	0.043	0.044	0.0
	2004	0.096	0.177	0.182	1.044
	2003	0.107	0.176	0.181	0.860
	2002	0.112	0.171	0.176	0.702
	2001	0.113	0.164	0.168	0.572
	2000	0.111	0.154	0.158	0.457
	1999	0.107	0.144	0.146	0.369
	1998	0.101	0.132	0.134	0.295
	1997	0.093	0.120	0.121	0.233
	1996	0.084	0.108	0.109	0.185
	1995	0.075	0.094	0.094	0.148
	1994	0.065	0.084	0.084	0.116
	1993	0.055	0.074	0.073	0.093
	1992	0.045	0.064	0.063	0.071
	1991	0.035	0.055	0.054	0.059
	1990	0.025	0.046	0.045	0.047
	1989	0.016	0.039	0.038	0.037
	1988	0.011	0.032	0.031	0.029
	1987	0.008	0.025	0.024	0.021
	1986	0.008	0.029	0.028	0.067
SUM:		1.288	1.932	1.953	5.406

Comment: Current output unit numbers are IOUREP=6 IOUERR=6 IOUASK=2

Appendix D

Calculation Procedure: Estimating the Effects of Gasoline/Oxygenate Blend Use on Fleetwide Emissions

Appendix D

Calculation Procedure: Estimating the Effects of Gasoline/Oxygenate Blend Use on Fleetwide Emissions

This appendix provides additional details on the method described in Section 4 and used in Appendix C. The first part of this covers how the tables of adjustment factors (Tables 4-1 to 4-17) were calculated, and the second covers what is done with those adjustment factors to calculate the fleetwide effect of a given alternative fuel scenario. This information can be used to automate the calculation process, if desired. Readers choosing to do manual calculations, and not needing to understand all aspects of how the tables of adjustment factors were calculated need not read this Appendix.

The process of estimating the effects of gasoline/oxygenate blends on fleetwide emissions includes two phases. In the first phase, the planner considers how emissions of vehicles from each model year and vehicle class combination within the fleet will be affected by the new fuel(s). If more than one fuel will be used, then these effects should account for mixing of the fuels. The planner must run the special version of the MOBILE3 (named M3.BYMY), or MOBILE4 when available, to provide specific information about the emissions of model year/vehicle class combinations within the fleet when using pure gasoline fuels. The inputs to the special version are the same as inputs to a standard MOBILE3 run, and should represent the best available information regarding the fleet. The second phase of the process involves the repeated application of four weighting and summation equations. This phase is suitable for computer processing.

1.0 Phase 1: Effects on Specific Technology/Fuel System Groups

1.1 Defining Technology and Fuel System Groups

A technology group is a group of vehicles whose emissions, due to similar technology, could be expected to respond in roughly the same way to the use of alternative fuels. For example, a typical gasoline fueled fleet can be divided into subfleets by exhaust technology; one such group includes vehicles without catalytic converters, another includes vehicles with catalytic converters and open loop fuel control systems, and a third group includes vehicles with closed loop fuel control systems. This classification is used when considering the effects of a given fuel on exhaust emissions.

Another classification divides the fleet into two groups by fuel system. One group contains the vehicles with carburetors, and the other group contains vehicles with fuel injection. This classification will be used when considering the fuel-related effects of evaporative emissions. The terms, "technology fraction" and "fuel system fraction" refer to the fraction of the fleet, determined by sales data, which are part of the technology or fuel system group. They are represented in calculations by $SF_{t,myr,class}$ and $SF_{fs,myr,class}$, respectively.

1.2 Technology-Specific Adjustment Factors

The planner must determine the effect of the alternate fuel on the exhaust emissions of each technology group within the fleet. This effect is expressed in terms of a technology specific adjustment factor ($AF_{t,pol}$) which will be multiplied by the average emissions of the indicated pollutant from vehicles within the group when using pure gasoline to find the average emissions of the group when using the alternate fuels.

These calculations will proceed under the assumption that the exhaust emissions from a fleet that is using more than one fuel will equal the weighted average of the emissions of the fleet when using the individual fuels (i.e., commingling does not affect exhaust). For example, consider a fleet that uses blend A 75% of the time and blend B 25% of the time. If the closed loop vehicles achieve a 12% reduction (adjustment factor of 0.88) in CO when operating on blend A and a 4% reduction (adjustment factor of 0.96) when operating on blend B, then the emission change for the whole technology group is calculated as:

$$AF_{t,co} = 0.75 * 0.88 + 0.25 * 0.96$$

$$CO_{blend} = CO_{gasoline} * AF_{t,co}$$

Table 3-1 lists the adjustment factors for exhaust emissions of each of the three technology groups when using two different types of fuel. Note that the adjustment factors for exhaust are dependent on the oxygen content and RVP of the blend, and not necessarily on the species of the oxygenate.

1.3 Fuel System Specific Adjustment Factors

Finding the fuel system specific adjustment factors (AF_{fs}) for evaporative emissions is more complicated than the procedure for exhaust. The planner must determine the effects of the fuels on both hot soak and diurnal emissions from each technology group. These effects could include commingling if more than one type of blend is used in the fleet or if blends and gasoline are used in the fleet. The procedure for finding the effects of commingling are described in Appendix A. The effects must be weighted together to find the adjustment factor for each fuel system group. This weighting process is done by multiplying the evaporative emissions of vehicles using pure gasoline by the appropriate adjustment factors (from Tables 3-2 to 3-4 or using a commingling calculation when appropriate), and calculating the g/mi for both the reference case (pure gasoline) and the fuel blend case. The equation which relates hot soak and diurnal emissions in g/test to g/mi emission factors is:

$$\text{Evap VOC (g/mi)} = 0.0981 * \text{H.S. (g)} + 0.0322 * \text{Diurnal (g)}.$$

The adjustment factor, AF_{fs}, can be found by dividing the adjusted g/mi emissions by the reference case emissions. For example, consider a city in which gasoline has an RVP of 11.5 psi, and which plans to implement a program of 100% use of a gasohol blend (10% ethanol, no volatility adjustment). From Table 4-2, the reference evaporative emissions from carbureted vehicles in this fleet are 4.27 g/test hot soak, and 9.09 g/test diurnal, yielding a 0.71 g/mi emission factor. From Table 3-2, the appropriate emission changes for this vehicle group and this fuel use scenario are +35.28% and +80.1% for hot soak and diurnal, respectively, which indicate adjustment factors of 1.353 and 1.801. Applying these adjustment factors:

$$\text{H.S.}_{blend} = 4.27 \text{ g} * 1.353 = 5.78 \text{ g}$$

$$\text{Diurnal}_{blend} = 9.09 * 1.801 = 16.37 \text{ g}$$

$$\text{Evap}_{blend} = 0.0981 * 5.78 + 0.0322 * 16.37 = 1.09 \text{ g/mi}$$

$$AF_{fs} = 1.09 / 0.71 = 1.5$$

1.4 Evaporative Emissions, Gram/Mile Reference Levels

The procedure uses the assumption that exhaust emission levels from different technology groups within a given model year and vehicle type are the same when fueled with gasoline.

This reasonable assumption simplifies later calculations, since the contribution of a technology group to the total exhaust emissions of the model year/vehicle type are proportional to the sales fraction of the group within the model year/vehicle type.

This assumption is not used in the case of evaporative emissions, because the evaporative emissions of the two fuel system groups can be very different. The planner must determine the relative levels of evaporative emissions (from the reference case, in g/mi) so that the contribution of the groups to the evaporative emissions of a given model year/vehicle type can be determined. These levels are relative to each other; the calculation procedure which uses them is not sensitive to the absolute levels. For example, if the reference levels are actually 0.5 g/mi for the fuel-injected group and 1.0 g/mi for the carbureted group, then the results will be the same if the levels are chosen at 2.0 g/mi and 4.0 g/mi, respectively.

One choice of the reference evaporative emission levels will suffice for the whole fleet. The RVP of the base fuel determines which levels should be used. Table 4-2 lists recommended levels for different fuels of four different RVP's. If the modelled fleet uses fuel of an average RVP not listed in Table 4-2, then the levels can be interpolated from those listed.

2.0 Phase II: Calculations

Phase II of the procedure involves the repeated application of four equations to the values chosen above, the sales fractions of the individual model years, and the output from the special version of MOBILE3 (or MOBILE4). This version of MOBILE3 lists the emission factors of each pollutant by each model year of the four gasoline fueled vehicle classes. These emission factors are already weighted by the travel fraction of the model year within the vehicle class, so that the sum over all model years equals the emission factor (on unblended gasoline) for that vehicle class.

2.1 Adjustment Factors; Exhaust

The first equation finds the adjustment factor, $AF_{pol,myr,class}$ to the base exhaust emissions for each pollutant, model year and vehicle class. The calculation is a simple weighting of the technology-specific adjustment factors by the sales fractions ($SF_{t,myr,class}$) of the technology groups within the model year/vehicle class.

$$AF_{pol,myr,class} = \& _t SF_{t,myr,class} * AF_{t,pol}$$

key

pol:	pollutant indicator; exhaust HC, CO, NOx
class:	vehicle class indicator; LDGV, LDGT1, LDGT2, or HDGV
myr:	model year indicator
t:	technology indicator; no catalyst, catalyst and open loop, or catalyst with closed loop
$AF_{t,pol}$:	technology-specific adjustment factor for indicated pollutant
$SF_{t,myr,class}$:	sales fraction of technology group within model year and vehicle class
$AF_{pol,myr,class}$:	adjustment factor to pollutant of model year/ vehicle class

This equation must be applied for each of the exhaust pollutants to each vehicle class and model year.

2.2 Adjustment Factors; Evaporative VOC

The second equation finds the adjustment factor $AF_{pol,myr,class}$ to the base VOC evaporative emissions. The calculation is a slightly more complicated weighting of the fuel system-specific adjustment factors by the reference emission levels and the sales fractions.

$$X = \& _{fs} SF_{fs,myr,class} * RL_{fs}$$

$$Y = \& _{fs} SF_{fs,myr,class} * RL_{fs} * AF_{fs}$$

$$AF_{pol,myr,class} = Y / X$$

key:

fs:	indicator of fuel system group; carbureted or fuel injection
myr:	model year indicator
class:	vehicle class indicator, LDGV, LDGT1, LDGT2, HDGV
pol:	pollutant indicator, in this equation indicates only evaporative VOC
$SF_{fs,myr,class}$	sales fraction of fuel system group within model year/vehicle class
RL_{fs}	relative evaporative emission level of the indicated fuel system group
AF_{fs}	adjustment factor to evaporative emissions of indicated fuel system group
$AF_{pol,myr,class}$	adjustment to emission factor of indicated pollutant from model year/vehicle class

Tables 4-1 to 4-17 list the adjustment factors for several fuel use scenarios which were calculated using this method. The planner may use these adjustment factors if the expected fuel scenario in the area of interest fits one of the scenarios listed.

2.3 Adjusted Emission Factors, by Model Year

Now that the adjustment factors have been determined for all pollutants, model years, and relevant vehicle classes, the planner must apply them to the emission factors listed by M3.BYMY. M3.BYMY has a special section of output which lists emission factors of exhaust HC, CO, and NOx, and evaporative HC by model year for four gasoline-fueled vehicle classes. These emission factors have already been weighted by the appropriate travel fractions, and the sum of these values within a given vehicle class equals the composite emission factor for that class when using pure gasoline. To find the composite emission factor for the class when using alternative fuels, the planner multiplies each of the emission factors listed by the M3.BYMY model by the adjustment factor for that pollutant, model year and vehicle class, and sums the results within each vehicle class as follows:

$$CEF_{pol,class} = \underset{myr}{\&} EF_{pol,myr,class} * AF_{pol,myr,class}$$

key:

myr:	model year indicator
class:	vehicle class indicator, LDGV, LDGT1, LDGT2, HDGV
pol:	pollutant indicator, in this equation indicates all four pollutants
$EF_{pol,myr,class}$	emission factor listed by M3.BYMY model for each pollutant, model year, and vehicle class
$AF_{pol,myr,class}$	adjustment to emission factor of indicated pollutant from model year/vehicle class
$CEF_{pol,class}$	emission factor of indicated pollutant for given vehicle class after adjustment for alternate fuel scenario

2.4 Fleetwide Emission Factors

The last step in the calculation procedure finds the fleetwide emissions when the alternate fuels scenario is in effect. This calculation is similar to the one which MOBILE3 uses to weight by VMT mix and add together the vehicle class emission factors, except that the original vehicle class emission factors for the four affected vehicle classes are replaced by the new factors. The VMT mix and the original emission factors by vehicle class are listed in the output of M3.BYMY. The following equation summarizes the final step:

$$FEF_{pol} = \sum_{class} CEF_{pol,class} * VMT_{class}$$

key:

pol:	pollutant indicator, includes all four pollutants
class:	Vehicle class indicator, includes all eight vehicle classes
$CEF_{pol,class}$:	emission factor of indicated pollutant by vehicle class, use values calculated in earlier procedure for LDGV, LDGT1, LDGT2, and HDGV classes, otherwise use values from M3.BYMY output
VMT_{class}:	travel fraction of vehicle class within fleet, as listed in model output
FEF_{pol}:	fleetwide emission factor of indicated pollutant