ABSTRACT

UNCMOBILE4 is a mobile source emission factor model that has been designed to include the benefits of a fuel switch toward methanol fuel in future scenarios. UNCMOBILE4 is a modified version of EPA's emission factor model MOBILE4. MOBILE4's overall structure is kept. Two vehicle classes, Light Duty Flexible fueled vehicles running on Methanol (LDFM) and Light Duty Flexible fueled vehicles running on Gasoline (LDFG), have been added to the original eight vehicle classes of the EPA model. UNCMOBILE4 provides HC, CO and NOx average emission rates from in-use methanol-fueled cars and from vehicle fleets of changing composition under a wide range of conditions. The LDFM and LDFG calculations are mostly based on data from Gabele (1990). Some correction factor calculations are the same as for Light Duty Gasoline Vehicles (LDGV) until explicit research data becomes available. The model has been prepared in a way that the extensive but not yet released data from the Auto/Oil study on flexible fueled cars can be inserted.

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LIST OF ABBREVIATIONS

ATP	Anti-Tampering Program
CF	Correction Factor
CO	Carbon Monoxide
DR	Deterioration Rates
EPA	(U.S.) Environmental Protection Agency
EF	Emission Factor
FFV	Flexible Fueled Vehicles (=LDF)
FTP	Federal Test Procedure
gpg	grams per gallon
gpm	grams per mile
HC	(total) Hydrocarbons
HDDV	Heavy Duty Diesel Vehicles
HDGV	Heavy Duty Gasoline Vehicles
LDDT	Light Duty Diesel Trucks
LDDV	Light Duty Diesel Vehicles
LDF	Light Duty Flexible Fueled Vehicles
LDFG	Light Duty Flexible Fueled Vehicles running on gasoline
LDFM	Light Duty Flexible Fueled Vehicles running on M85
LDF	Light Duty Flexible Fueled Vehicles (=FFV)
LDGT1	Light Duty Gasoline Trucks class 1
LDGT2	Light Duty Gasoline Trucks class 2
LDGT	Light Duty Gasoline Trucks
LDGV	Light Duty Gasoline Vehicles
M85	Blend of 85% methanol and 15% gasoline
MC	Motorcycles
mpg	miles per gallon
NOx	Nitrogen Oxides, sum of nitrogen monoxide and nitrogen dioxide
RVP	Reid Vapor Pressure
SIP	State Implementation Plan
VRS	Vapor Recovery System
ZML	Zero Mile Level

1. INTRODUCTION

Mobile source's emissions of hydrocarbons, nitrogen oxides, and carbon monoxide are considered to be important contributors to urban ozone. Control devices for gasoline cars have been employed to reduce emissions of new and in-use vehicles by 92 and 78 percent, respectively, over the past 20 years. The associated development of new vehicle emission standards is shown in TABLE1. Further efforts to reduce emissions from cars powered with conventional gasoline "must now contend with a law of diminishing returns" [Gabele, 1990].

Cleaner fuels are currently being examined to determine their ability to improve air quality. Alternative, carbon-based fuels might have the potential to mitigate urban ozone and carbon monoxide levels during the inevitable transition toward electrically-powered and hydrogen-powered transportation. At this time, the most promising alternative fuel with both economically and environmentally attractive attributes appears to be methanol [Gabele, 1990]. Methanol fuels are also being considered because of their ability to reduce American dependency on foreign oil and to reduce gases contributing to global warming.

As a crucial step in determining future air quality, complex photochemical models such as the Urban Airshed Model need realistic and reliable emission inventories for in-use highway fleets. For this task, the United States Environmental Agency developed the MOBILE series of vehicle emission rate models of which MOBILE4 is the latest version. MOBILE4 is a very complex set of 151 FORTRAN subroutines, functions, and block data which calculates emission factors in units of g/mile under a wide range of user-specified environmental conditions.

This paper introduces the vehicle emission model UNCMOBILE4 that has been designed to be able to include the benefits of a fuel switch toward methanol blends in future scenarios. UNCMOBILE4 is a modified version of EPA's MOBILE4 and provides additionally HC, CO and NOx emission rates from in-use methanol-fueled cars and from vehicle fleets of changing composition under a wide range of conditions.

Two vehicle classes, Light Duty Flexible fueled vehicles running on Methanol (LDFM) and Light Duty Flexible fueled vehicles running on Gasoline (LDFG), have been added to the original eight vehicle classes of the EPA model. While the overall structure of MOBILE4 is kept, numerous subroutines had to be changed and many others added to account for base emission rates and dependencies different from those for conventional cars.

TABLE1: Exhaust and evaporative emission standards for new Light Duty Vehicles[1]

Year	Exhaust HC	Exhaust CO	Exhaust NO_x	Evaporative HC
1972	3.4 gpm	39 gpm	-	2.0 g/test
1973-74	3.4 gpm	39 gpm	3.0 gpm	2.0 g/test
1975-76	1.5 gpm	15 gpm	3.1 gpm	2.0 g/test
1977	1.5 gpm	15 gpm	2.0 gpm	2.0 g/test
1978-79	1.5 gpm	15 gpm	2.0 gpm	6.0 g/test
1980	0.41 gpm	7 gpm	2.0 gpm	6.0 g/test
1981	3.4 gpm	3.4 gpm	1.0 gpm	2.0 g/test

Notes:

1 Different test procedures have been used since the early days of emission contol which vary in stringency. The appearence that standards were relaxed is incorrect and arises from test procedure changes.

UNCMOBILE4 cannot yet be assumed to provide reliable emission factors for future methanol cars since it is not based on the most recent data and it partly relies on unchecked assumptions. So far, mostly data from Gabele (1990) has been utilized. Thus, the model has been prepared in a way that the extensive but not yet released data from the Auto/Oil study on flexible fueled cars can be inserted. UNCMOBILE4 can also serve as a pattern for including other vehicle classes instead of, or additional to, flexible fueled cars to MOBILE4 or MOBILE4.1.

2. METHANOL CARS

2.1 Methanol Car Technology and Economy

Flexible fueled vehicles (FFV) are designed for using gasoline fuel or any alcohol/gasoline blend up to 85% methanol. An electronic sensor in the fuel delivery system senses the methanol content of the mixture, and engine parameters are adjusted appropriately for proper combustion. Like all methanol cars, they also need modified fuel tanks and fuel delivery systems to withstand methanol's corrosive nature. Although FFV cannot provide the same emission benefits as dedicated vehicles, they are likely to be used during a transition period when gasoline is phased out and alternative fuel is phased in.

Dedicated methanol vehicles can only use fuel composed of at least 85% methanol. These vehicles, if running on M100 (100% methanol), promise the greatest emission benefits but are difficult to start at ambient temperatures below 60 F. If this problem can be solved, they might become the best option for future use.

Because of its high oxygen content methanol contains only about one-half of the energy per gallon of gasoline. Thus, methanol cars yield comparably much lower miles per gallon values. But other properties make methanol a more energy efficient fuel than gasoline. Its higher octane rating permits a higher compression ratio, its wide flammability limits allow good combustion while operating lean, and its higher energy output permits smaller engines while providing the same performance. These effects are believed to add up to a 30 percent increase in overall vehicle efficiency for dedicated vehicles. [EPA, 1989]

Methanol fuel prices can be competitive with gasoline at current world oil prices. M85 pump prices could be 68 to 74 cents per gallon, including costs for distribution, retail markup, and fuel taxes. The lower energy content of M85 and its slightly higher efficiency yield to a projected gasoline retail price equivalent of 114 to 124 cents per gallon. M100's pump price could be 60 to 67 cents per gallon. Considering the lower energy content and the 30 percent higher efficiency expected for an optimized, dedicated vehicle, the projected gasoline retail price equivalent yields to 92 to 103 cents per gallon. The retail prices can be lowered even further if methanol is produced on larger scale. Thus, the price for M85 and M100 is competitive with todays gasoline prices and even lower than those for premium gasoline, which is the natural competitor for the high octane methanol fuels [EPA,1989].

EPA estimates the costs for dedicated methanol vehicles as the same as for future gasoline vehicles. Flexible fueled vehicles might be up to $300 more expensive, among other things because a fuel sensor is needed [EPA, 1989].

2.2 Composition of Methanol Car Emissions

The precise forecasting of emissions from future methanol cars and fleets is extremely difficult, since the emissions depend on numerous factors. Exhaust, evaporative, refueling, and running loss emissions are substantially different for dedicated methanol vehicles and flexible fueled cars. For the latter ones, the emissions are a factor of the fleet portion actually running on a methanol blend, and for both vehicle classes a function of the gasoline content of the fuel supplied.

The methanol car technology is still evolving, and parameters for the eventual, optimized methanol vehicle are not yet known. The emission levels finally attainable and the cars fuel efficiencies are still hard to predict. Also emission standards and required control technologies as well as which vehicle classes will be affected is not yet exactly known.

There is strong evidence that far lower emissions than for gasoline vehicles finally can be achieved by at least certain kinds of methanol vehicles [EPA,1988]. Therefore future standards for these cars might adjust to the advanced technology. The currently proposed standards for light duty methanol vehicles are the same as for LDGV, for HC on a carbon mass basis [Dunker, 1990]. Modeling on the basis of these standards would mean that only the composition of the emitted hydrocarbons changed. The other approach, taken by UNCMOBILE4, is to utilize actual test data for calculating the model's base emission rates and corrections.

Whether or not methanol vehicles will play a role as a future vehicle fuel, and the applied technology, and the future emission rates, are a function of environmental and economic policies on federal and state level. A switch to any kind of alternative fuel requires major and cost-intensive changes and perhaps market share losses in two of the biggest and most influential industrial branches. The automobile industry and possibly even more the oil industry will be highly affected. They might prefer a transition to oxygenated fuels, so strong opposition might arise from them.

Nevertheless, a number of research projects on methanol cars have been conducted and allow qualitative and quantitative assessment of their emissions. It appears that the major difference to gasoline-powered cars, at least in terms of ozone forming potential, is the composition of the emissions and to a lesser extend their absolute amounts.

The emissions from flexible fueled vehicles running on M0, that is pure gasoline, are generally considered to be the same as for regular light duty gasoline vehicles. Blends containing more methanol produce similar amounts of exhaust regulated emissions (organic material, carbon monoxide, and nitrogen oxides). Ambient temperature affects the emission rates in the same matter as for gasoline cars: organic and CO emissions increase strongly at lower temperatures whereas NO_x is less affected. Mass exhaust emissions stay virtually constant above 75 F. [Gabele, 1990]

Gabele (1990) tested flexible fueled cars with M0, M25, M50, M85, and M100. He states that, while increasing the fuel's methanol content, "formaldehyde and methanol comprise increasingly greater portions of the material while hydrocarbons comprise less." Both compounds also increase strongly at lower temperatures. [Gabele, 1990] Testing an early model FFV, Gabele found that benzene, 1,3-butadiene, and acetaldehyde emissions are lower for M85 use than for M0 use. Exhaust methane increases with increasing methanol content, whereas the composition of the remaining hydrocarbons is not significantly affected. Gabele found similar portions of paraffins, olefins, and aromatics of total HC for M0 and M85. [Gabele, 1991]

Evaporative emissions increase with fuel volatility, that is with decreasing methanol content, and increase with temperature. Diurnal emissions are much greater in magnitude and more sensitive with respect to temperature and fuel volatility than hot soak emissions. The gasoline portion of methanol fuel blends, even if small, contributes significantly to the emissions. 40 % of the M85 exhaust carbon is gasoline related. [Jeffries, 1991] Gabele also found the hydrocarbon component of evaporative emissions from M85 to dominate over the methanol component. [Gabele, 1990]

Methanol is released into the atmosphere as unburned fuel in exhaust and evaporative emissions. Aldehyde derivates such as formaldehyde are combustion products in the exhaust gas. A great portion of the total formaldehyde emissions occur during the first part of the cold start mode. [Gabele, 1990]

2.3 Methanol Car Emissions and Urban Ozone

The reduction of urban ozone as a secondary pollutant has proven to be much more difficult than that of the primary pollutants. The National Ambient Air

Quality Standard (NAAQS) for ozone is a 1-hour averaged concentration of ozone of 0.12 ppm not to be exceeded more than once per year at any location over a three year period. It is still violated in 60 major urban areas in the United States. Los Angeles has exceeded the standard in the late eighties some 140 times per year (Seinfeld, 1988).

The hope that a switch toward methanol as an automobile fuel could reduce ambient ozone levels arises mostly from the altered composition of the alternative fuel exhaust and particularly of its organic emissions. The volatile organic compounds (VOC) are expected to show a lower degree of reactivity than those from gasoline emissions. Methanol makes up a large portion of the organic exhaust and evaporative emissions and is considered to have a much lower reactivity than other organic compounds. The fraction of methane, another low reactive compound, is increased for methanol vehicles. Also formaldehyde is emitted at a higher rate than by gasoline cars. Formaldehyde is considered to be a very reactive compound and a strong source of radicals.

Extensive research projects are underway to verify and quantify the benefits of the relative reactivity of methanol car emissions. They utilize smog chamber experiments and complex photochemical models such as the Urban Airshed Model (UAM). It is difficult to reliably predict the effects of alternative fuels because of the complexity of the concept of reactivity.

Reactivity is defined as "the extent to which a compound or a mixture of compounds contributes to atmospheric oxidation of VOC, oxidation of NO to NO_2, and subsequent O_3 production in the ambient atmosphere" [Jeffries et al., 1991]. It arises from complex interactions among all reacting species. Thus, it is a non-linear function of numerous atmospheric conditions such as the NO_x-HC-ratio, and any "reactivity scale" for VOC compounds is necessarily relative.

To illustrate the complexity of the issue, Jeffries states that most of the ozone is formed by the least reactive compounds. CO, methane, and alkanes, form up to half of the urban O_3 simply because of their high concentrations. Highly-reactive species such as olefines, xylenes, and emitted aldehydes are the primary source of "new radicals", which are required for ozone formation. The reactions for only very few of these compounds are precisely understood. Thus, further research has to be done to refine the chemical mechanisms utilized in the computer models that could evaluate alternative fuels. [Jeffries et al., 1991]

Currently, alternative fuels can be included in future air quality scenarios and State Implementation Plans (SIP) without utilizing photochemical models by following EPA guidelines. These are contained in EPA's "Guidance on Estimating

Motor Vehicle Emission Reductions from the Use of Alternative Fuels and Fuel Blends" (1988), and represent relatively old research data. This document describes methods and assumptions for estimating the impact from the use of gasohol, Methyl Tertiary Butyl Ether (MTBE) blends, compressed Natural Gas (CNG), and methanol blends - including M85 and M100 - on vehicle HC, CO, and NO_x emissions.

The actual credit for methanol car use would depend on the emission levels of the proposed vehicle technology for that area. EPA specifies the reductions for methanol vehicles just meeting the emission standards, for those well below the standards, and for those with intermediate emission levels. The credit is to be applied to MOBILE4's non-methane HC exhaust and evaporative model year emission factors; CO and NO_x emission levels are unchanged.

2.4 Other Environmental Impacts

Whereas all carbon-based fuels necessarily emit gases contributing to the greenhouse effect, their amount can be reduced if gasoline is replaced by alternative fuels. Whether using methanol could yield global warming benefits, depends mostly on the way it is produced.

Currently, the production from natural gas is economically favored. If natural gas which is now vented or flared is used, a large warming benefit will accrue, since such gas is currently being wasted while adding huge amounts of carbon dioxide and methanol to the greenhouse gas burden. Using coal as a methanol feedstock with current technologies could nearly double greenhouse gas emissions due to large losses at the mine and at the production plant. The greatest benefit would arise from using cellulose, biomass or other renewable feedstock, since such materials are not stored carbon. Their growth would remove the same amount of carbon dioxide from the atmosphere as their combustion would emit. [EPA,1989]

Significant reductions in the number of cancer cases are projected for replacing gasoline by methanol since emissions of hydrocarbon air toxics such as benzene, 1,3-butadiene or polycyclic aromatic matter would be reduced or eliminated. Methanol is not generally considered a toxic air pollutant. Formaldehyde is classified by EPA as a probable human carcinogen. This issue is often raised as a concern since the levels of initially emitted formaldehyde are higher for tested methanol cars, even though control technology could reduce them to gasoline levels. Methanol is not expected to increase the number of cancer cases since the decreased number of indirect formaldehyde formed photochemically is expected to offset any increase in direct formaldehyde emissions. Ambient concentrations of both methanol and formaldehyde are believed to remain well below the levels of acute toxicity. [EPA,1989]

3. THE CURRENT MOBILE4 PROGRAM

MOBILE4 is a computer program designed to estimate average mobile source emissions in units of g/mile. The model provides both current and future emission rates from highway vehicle fleets under many environmental conditions. The model weights emissions from vehicles of the most recent 20 model years to obtain fleet emissions as of January 1 of the requested calendar year. The emission factors are adjusted to compensate for numerous factors. Speed, temperature, and cold/hot driving mode mix are most influential, tampering and fuel volatility also have a major impact.

The results are split into the following compound classes: total HC, exhaust HC, evaporative HC, refuel losses HC, running losses HC, exhaust CO, and exhaust NO_x. The emission factors are also specified for eight vehicle classes: Light Duty Gasoline Vehicles (LDGV), Light Duty Gasoline Trucks 1 (LDGT1), Light Duty Gasoline Trucks 2 (LDGT2), Heavy Duty Gasoline Vehicles (HDGV), Light Duty Diesel Vehicles (LDDV), Light Duty Diesel Trucks (LDDT), Heavy Duty Diesel Vehicles (HDDV), and Motorcycles (MC).

MOBILE4 consists of an integrated set of 151 FORTRAN subroutines. It is the most recent of EPA's MOBILE series of motor vehicle emission factor models. MOBILE4.1, which allows the evaluation of oxygenated fuels, is expected to be released very soon.

MOBILE4 provides a flexible analytical tool for a wide range of air quality planning functions. Except for California, EPA requires the motor vehicle emission inventories in all ozone, CO, and NO_2 SIP revisions to be based on the latest MOBILE version.

MOBILE4 supplies four types of formatted reports. Two types of "numeric" output are suitable for use as an input file for subsequent computer analysis. Two types of "descriptive" output are more suitable for visual inspection and analysis and for the users record.

3.1 Data base

The program uses the calculation procedures and extensive emission factor data presented in EPA's "Supplement A to Compilation of Air Pollutant Emission Factors - Volume II: Mobile Sources" (1991). For current exhaust emission rates, dynamometer tests under conditions of the Federal Test Procedure (FTP) were performed. The data is specified into three sampling bags for the three operating modes: cold start, hot start, and hot stabilized mode. New as well as on-road vehicles were tested to determine zero mile level and deterioration rates.

Exhaust, hot soak, diurnal, crankcase, refueling loss, and running loss emissions as well as idle exhaust emissions were determined. Special emission testing programs were performed to determine various correction factors. For future emission rates, federal new-vehicle emission standards based on FTP are assumed. MOBILE4 contains extensive driving pattern data from chase car surveys determining the mix of operating modes as a function of average route speed as well as data for trips per day and miles per trip.

3.2 Mobile4 and UAM

MOBILE4 is utilized to provide mobile sources emission input for complex photochemical air quality models such as SAI's Urban Airshed Model (UAM), and thus is a crucial step in predicting future air quality, and in evaluating control strategies.

For use in the UAM, mobile sources inventories must be temporally, spatially, and chemically resolved to the level of the other modeling inputs: cells of 4 to 25 km2 for hourly emission estimates in species recognized by the Carbon Bond Mechanism Version IV (CB4).

This is done by the UAM's Emission Preprocessor System (EPS) which produces a gridded binary emissions file for input in the UAM. The emissions are allocated to the grid cells of the modeling region and split into the CB4 species NO, NO_2, OLE, PAR, TOL, XYL, FORM, ALD2, ETH, MEOH, ETOH, and ISOP. The applied factors are derived from EPA's Air Emission Species Manual (1988). The emission rates are transformed into hourly emission rates by diurnal variation factors and adjusted for the weekday by weekday variation factors. Among other data, HC, CO, and NO_x exhaust and evaporative emission factors, fractional vehicle miles travelled (VTM) and motor vehicle adjustment factors generated by MOBILE4 are is used as input for EPS.

3.3 Clean4

Based on MOBILE4, EPA developed CLEAN4, an emission factor model for evaluating "clean fuels". It applies adjustments that account for emission reductions from any two kinds of alternative fuel, for instance from M85 and M100 fuels.

The emission reduction factors for HC, CO, and NO_x, and for diurnal, hot soak, refueling, and running loss emissions are specified by the user in the one-time data entry. CLEAN4 does not contain any estimates of the effect of alternative fuels, but supplies the algorithm for evaluating them. The user also specifies sales fractions for the two alternative fuel vehicle classes for model year from 1993 on.

The adjustments are applied as multiplicative correction factors to light duty gasoline vehicle and trucks' emission factors. Thus, all internal MOBILE4 corrections apply unchecked as well for the "clean" vehicles. CLEAN4 does not specify vehicles running on alternative fuels in its output, they are included in the composite emission factors of LDV/T.

3.4 Performance of MOBILE4

The sensitivity of MOBILE4's output emission factors for several input parameter is shown in FIGURE1 through FIGURE3.

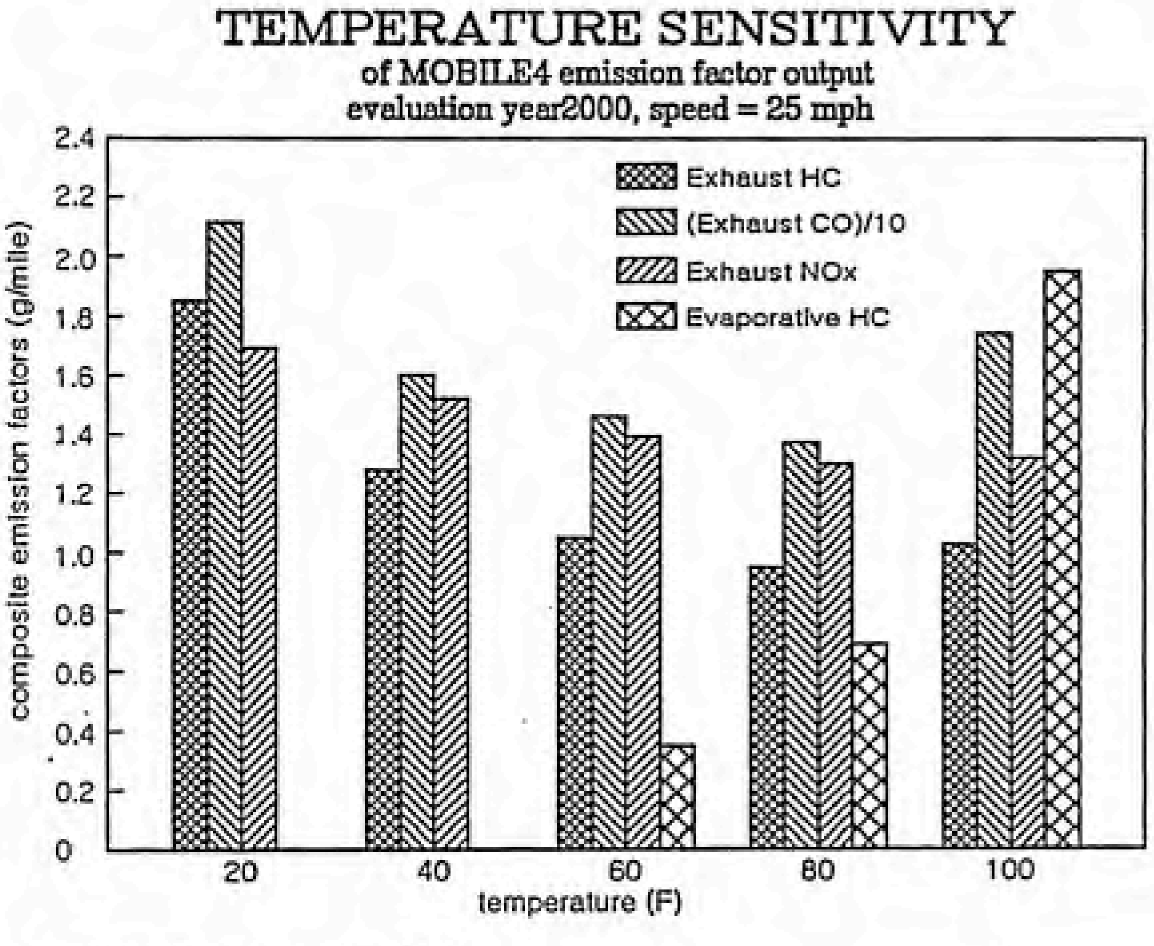

FIGURE1: Temperature sensitivity

The first figure shows HC, CO, and NO_x exhaust emissions as well as HC evaporative emissions as a function of temperature. All exhaust emissions are highest for low temperatures, are least at 80 F, and increase slightly for 100 F. CO appears to be most sensitive for temperature, NO_x least sensitive. MOBILE4 assumes evaporative emissions to be zero for temperatures less or equal to 40 F. Evaporative emissions increase exponentially with temperature and exceed exhaust HC emissions at 100 F.

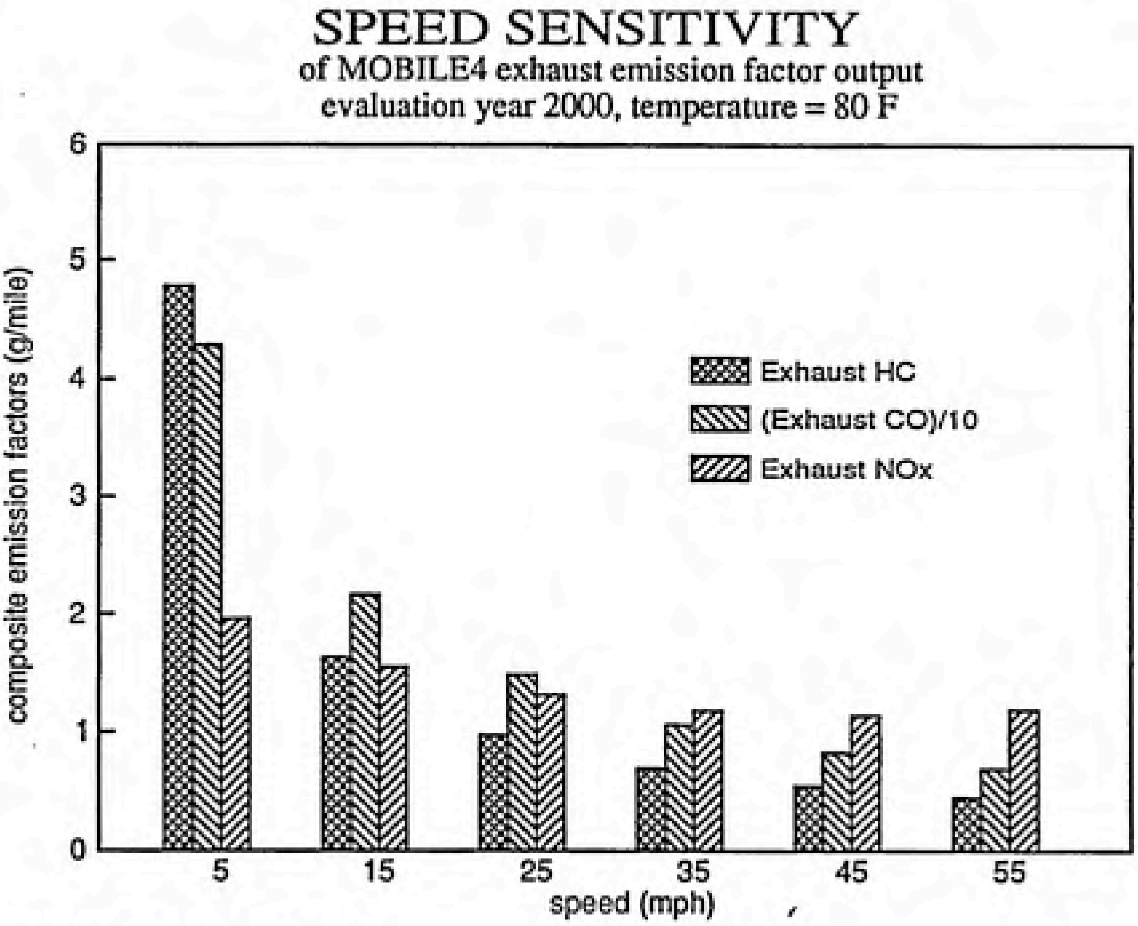

FIGURE2: Speed sensitivity

Exhaust emissions are also a function of average vehicle speed. MOBILE4 models the g/mile emission factors highest for very low speeds. The exhaust emissions reach a minimum for speeds around 50 mph. Exhaust emissions actually increase again for even higher speeds but this is not shown by MOBILE4 since its maximum input speed is 55 mph. HC exhaust emissions are very sensitive for speed, CO emissions are sensitive to a somewhat lesser extend, and NOx is least sensitive.

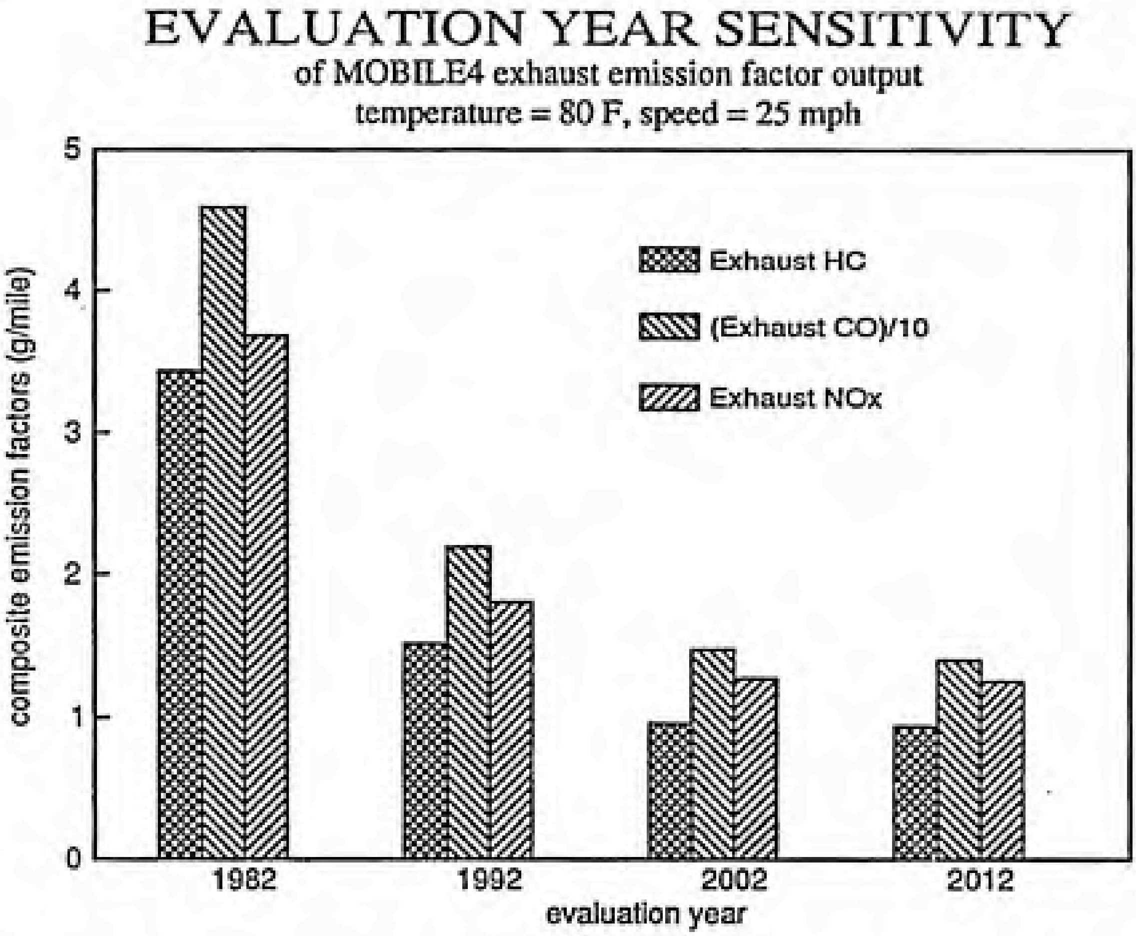

FIGURE3: Evaluation year sensitivity

The emission factors decrease with time, as shown here for fleet average composite exhaust HC, CO, and NOx emission factors. The per-car emissions decrease since older vehicles, built for higher emission standards, phase out and are replaced by newer vehicles. MOBILE4 does not contain projections for lower future emission standards. The zero mile emission levels for future cars are assumed to be the same as for current vehicles since no explicit information on future standards is available yet. Therefore, the calculated emissions approach and finally reach a constant level, after all old higher-standard vehicles are replaced.

However, it is important to note that MOBILE4 models average per-car emission factors rather than summed-up total emissions from the entire fleet. Total fleet emissions might stay constant or even go up despite of decreasing average emission levels, if the number of vehicles grows.

4. UNCMOBILE4

4.1 Technical Differences to MOBILE4

The vehicle emission model UNCMOBILE4 has been developed to include flexible fueled cars in future vehicle fleet emission scenarios. It is a modified version of EPA's MOBILE4 which does not offer this opportunity.

Two vehicle classes, Light Duty Flexible fueled vehicles running on Methanol (LDFM) and Light Duty Flexible fueled vehicles running on Gasoline (LDFG), have been added to the original eight vehicle classes of the EPA model. Thus, the calculation of composite emission factors becomes possible for a vehicle fleet stepwise or partly switched toward methanol vehicles. The user only needs to specify annual sales fractions for FFV, the portion of FFV actually running on M85, M85's Reid Vapor Pressure, and to set two execution controlling flags.

The calculations for the eight old classes are kept unchanged. Only their vehicle miles travelled (VMT) share is reduced by the internal calculated VMT portion of LDFM and LDFG for each calendar year. As far as the currently available FFV emission factor data allows, the LDFM and LDFG calculations follow the pattern of those for the LDGV. Since this data is not as detailed as those utilized by MOBILE4, they are simplified at some points. Other correction factor calculations are taken unchanged from LDGV until explicit research data becomes available, if they can be assumed to be similar. Driving pattern data such as vehicle age specific accumulated mileage, trips per day, and miles per day are the same as for LDGV. It is important to note that UNCMOBILE4's HC emission factor output reflects the total organic emissions, including hydrocarbons, methanol, and formaldehyde.

The advantage of keeping the original MOBILE4 structure is that as soon as new data such as those from Auto/Oil becomes available, it can easily be included in UNCMOBILE4's data basis. Depending on the nature of this data, further changes to the algorithm might be conducted. The LDF calculations finally become as sophisticated and detailed as for the other vehicle classes. This is unlike EPA's CLEAN model which only applies multiplicative correction factors to MOBILE4's vehicle classes to account for emission reduction due to alternative fuels. UNCMOBILE4 can also serve as a pattern for including other vehicle classes instead of, or additional to, FFV into MOBILE4 or MOBILE4.1.

No information is available yet about in-use tampering rates and tampering effects for FFV. Nevertheless, it appears to be necessary to include tampering in the emission factor calculations since the arising excess emissions can be considerable. UNCMOBILE4 provides the opportunity to consider those effects for either one or both of the vehicle classes. If the control flags are set appropriately, tampering is assumed to add the same portion to the non-tampered emissions as for LDGV.

FFV running on gasoline are usually believed to produce the same g/mile emissions as LDGV. Depending on a control flag setting, all LDFG model year emissions can be set equal to those for conventional gasoline vehicles of that model year. Differences between LDGV and LDFG composite emission factors then arise only from different age distributions, that is registration mixes for the two classes.

The optional user input opportunities provided by MOBILE4 are not yet fully extended to cover the two new vehicle classes. The use of some of the control section flags is restricted to keep the comparability of the new and the old classes.

4.1.1 Data Base

The basic emission rates and correction factors for LDFM and LDFG calculations are mostly based on data published by Gabele (1990) who examined emissions from FFV. He measured HC exhaust and evaporative emissions as well as CO and NOx exhaust emissions for the gasoline/methanol blends M0, M25, M50, M85, and M100 at 40 F, 75 F, and 90 F.

The test vehicle investigated was a 1988 General Motors Variable Fuel Corsica with a 2.8-l six cylinder engine having a compression ratio of 8.9:1. The fuel system was port injection, the control loop was closed, and the mileage was 4500 miles. The test fuels were M0 (100% gasoline, 0% methanol) and M85 (15% gasoline, 85% methanol). The gasoline portion was indolene (certification fuel), the methanol was of laboratory grade specification. M0 had a Reid Vapor Pressure (RVP) of 9.0, M85's RVP was 8.0. The fuel economy was 22.0 mpg running on M0 and 13.4 mpg running on M85.

Data on emission rates and fuel economy were obtained both the Federal Test Procedure (FTP) and the Highway Fuel Economy Test. Three replicate tests were run for each temperature/fuel type combination. The organic emissions are calculated in accordance to the carbon mass equivalent method. The HC data utilized in UNCMOBILE4 is the sum of Gabele's data for methanol, formaldehyde, and hydrocarbons. All data used in the program is shown in TABLE1 through TABLE3.

<u>TABLE1</u>: Exhaust emissions (g/mile)

	HC	CO	NOx
40 F			
FFV on M85	1.86	8.50	0.28
FFV on M0	0.93	8.80	0.20
75 F			
FFV on M85	0.43	2.60	0.26
FFV on M0	0.32	2.60	0.22
90 F			
FFV on M85	0.51	2.40	0.31
FFV on M0	0.36	2.8	0.26

<u>TABLE2</u>: Hot soak and diurnal emissions (g/test)

	HS	DU
40 F		
FFV on M85	0.14	0.19
FFV on M0	0.19	0.26
75 F		
FFV on M85	0.25	0.49
FFV on M0	0.28	0.54
90 F		
FFV on M85	0.31	0.50
FFV on M0	0.41	1.05

TABLE3: Non-methane portion of HC exhaust

	40 F	75 F	90 F
FFV on M85	0.85	0.75	0.81
FFV on M0	0.90	0.90	0.87

The basic emission rates and correction factors for LDFM and LDFG calculations are mostly based on data published by Gabele (1990) who examined emissions from FFV. He measured HC exhaust and evaporative emissions as well as CO and NOx exhaust emissions for the gasoline/methanol blends M0, M25, M50, M85, and M100 at 40 F,75 F, and 90 F.

4.1.2 Execution Summary

UNCMOBILE4's structure and thus also the program execution are virtually the same as MOBILE4's. Its source code consists of 158 subprograms. These subroutines, functions, and block data are called by the program's driver MAIN or by other subprograms and may in turn call other subprograms. MAIN loops through three sections: input, calculation, and output. The most important subroutines are briefly described below. Subroutine's names are written in upper case.

Input

This section reads in the input and prepares the parameters and data for the subsequent calculation section. During one run, UNCMOBILE4 can evaluate several different scenarios, but only the first scenario can include methanol cars. The program utilizes one input data set that provides program control information and the data describing the scenarios. The user determines by the setting of the first flag (PROMPT) whether the program reads in by prompting the user for each following input or by reading a prepared, formatted input file. The input data set consists of three distinct sections.

CONSEC reads in the run title and the 18 flags of the Control section, either vertically using GETVER or horizontally using GETHOR. The flag setting controls input, output format, and execution of the program and consists of 17 flags. The flag setting also controls the format of the remainder of the input stream format of the output.

The One-time section is optional and is used to alter internal UNCMOBILE4 estimates to be locality-specific. This can include information on tampering rates, annual mileage accumulation rates or registration distributions by vehicle type and age, base emission rates, VMT mix, tampering parameters, inspection and maintenance program credits, anti-tampering program parameters, refueling emission controls, fuel volatility, and flexible fueled cars. ONESEC checks the flag values whether one-time data is expected and reads it in by calling other subroutines. This data is used for all scenarios of a run and replaces the corresponding default values hardcoded in BLOCK DATA. GETMET reads in the methanol car related user input. It screens the values for being in the ranges expected and calls QUITER if not.

The Scenario section details the individual scenarios of a run and reads in, among others, information on calendar year of evaluation, temperature, region (high or low altitude), and average speed by repeating PARSEC, GETSC1, and LOCAL for each scenario. LOCAL applies the same weathering to M85's RVP as to gasoline's RVP. Here calculated exhaust and evaporative temperatures are later also applied to LDF.

REGMOD calculates the evaluation year January 1 registration mix for the vehicles of each model year. LDGV's and LDDV's share is reduced by LDF's sales share of that model year, the light duty gasoline/diesel ratio stays the same. REGMOD also figures the vehicle age specific mileage accrual rates and evaluation year January 1 accumulated mileages. From that, REGMOD constructs vehicle age and class specific miles per day and trips per day values. In UNCMOBILE4, the data underlying these driving pattern calculations is the same for LDF and LDGV. YRTEST checks whether given years are in the allowed ranges. QUITER prints out error, warning, or comment messages and, depending on the severity of an error, may terminate the run.

Calculation

This section generates the requested composite emission factors. The calculation is performed for each vehicle type, each model year, and each of the compound classes. The algorithms for the two new vehicle classes are virtually the same as for LDGV and are described in detail in Chapter 4.1.3.

Base exhaust emission rates are calculated from the zero mile levels and deterioration rates. Correction factors for non-FTP conditions are applied, either as a multiplier or as an additive offset. These numbers are weighted together by travel fractions to generate emission factors by vehicle type and pollutant class, and then again weighted together by the normalized vehicle miles travelled (VMT) to produce a composite emission factors for each pollutant for the requested calendar year.

The calculation section is driven by EFCLAX. First, additive offsets and multiplicative correction factors are assembled in each scenario. GETCUM generates the average January 1 cumulative mileage distribution. TAMPER, by controlling the 16 tampering-related group of subroutines and functions, calculates tampering rates and emission impacts. BIGCFX and the associated subroutines figure the correction factors and corrections for speed, temperature, Reid Vapor Pressure (RVP) etc.

HC emission factors are calculated by HCCALX. It loops through each vehicle type and model year case, computing, correcting, weighting, and adding that case's contribution to the composite results. IGSFPT provides the gas/diesel sales fraction, IMSFPT points the LDF sales fraction year groups. BEF extracts the basic exhaust emission rate and applies correction factors. LDF exhaust emission factors are corrected for temperature by function EXTCOR. Function CH4COR determines the temperature-specific non-methane portion.

CCEVRT returns evaporative HC emission factors for all gasoline and methanol vehicles and motorcycles utilizing HOTSOK (hot soak emissions), DIURNL (diurnal), and CRANKC (crankcase), weighted by trips per day and miles per day. LDF hot soak emissions are extracted by subroutine EVMET and EVRVPC, and temperature corrected by function EVTCOR. RULOSS provides the running loss HC emission factors for gasoline and methanol vehicles. The refueling loss HC emission factors for the same vehicle classes are looked up in the table previously calculated by REFUEL. For calculation of CO and NOx emission factors, EFCALX loops through each pollutant, vehicle type, and model year case, utilizing BEF.

Output

On each successful scenario pass, OUTPUT routes the results to report unit 4. OUTHD4 echoes the run title and the field headers. Subroutines echo the optional user supplied input, like OUTMET does for methanol car input. OUTPOL selects which pollutant's values are to be printed, and OUTDT4 prints out user-supplied scenario data and the calculated emission factors.

Subroutines GETMET, IMSFPT, EVMET, EVRVPC, EVTCOR, EXTCOR, CH4COR, and OUTMET are newly created. REGMOD, EFCALX, REFUEL, HCCALX, CCEVRT, RULOSS, BEF, OUTDT4, and numerous BLOCK DATA are largely altered and extended. Most subroutines experienced minor changes. EFCALX, HCCALX, EVMET, EVRVPC, BEF, and EXTCOR are shown in Appendices C through H.

4.1.3 Modeling of emissions

Hydrocarbon exhaust emissions

HC exhaust emissions are modeled for all vehicle classes. In MOBILE4 as well as in UNCMOBILE4, they depend on vehicle mileage, temperature, tampering effects, speed, location-specific adjustments, and the fuel's RVP.

The uncorrected base emission rate for each model year/vehicle class group is determined from zero mile emission level (zml) and the deterioration rate (dr). Zml (g/mile) and dr ((g/mile)/10,000 miles) are assumed to be the same for both low and high altitude and are assumed to be constant for all model years.

The zero mile levels for LDFM and LDFG are the test results for the flexible fueled test vehicle investigated under Federal Test Procedure (FTP) conditions by Gabele (1990), running on M85 and M0, respectively. Since there is no data on deterioration rates yet, they are assumed to yield the same portion of the zml as for 1993 model year LDGV. Alike LDGV, LDF HC emissions have higher dr above a mileage of 50,000. The vehicle-age specific accumulated mileage for each model year, multiplied by the deterioration rates, is the same as for LDGV.

A correction factor is applied to the base emission rate to account for temperatures deviating from the FTP temperature (75 F). The multiplicative correction is figured by 2-point interpolation based on Gabele's FFV exhaust tests for 40, 75, and 90 F. If the temperature is below 40 F, the 40 F factor is applied, accordingly for temperatures above 90F.

If non-methane emission factors are requested, a temperature-dependent, multiplicative correction factor, generated also by 2-point interpolation from Gabele's (1990) data, is applied. If user-requested, an additive tampering offset is applied that yields the same portion of the non-tampered emission factor as for the LDGV of that model year. The tampering correction includes the effect of an anti-tampering program if one applies for the evaluation year.

Then, the emission factors are multiplied by the LDGV speed and optional adjustment correction factor. It accounts for an average speed different from the FTP average speed (19.6 mph). Thus, it is assumed that vehicle speed has the same quantitative impact on the gpm emissions for conventional gasoline vehicles and FFV. It also accounts for optional location-specific conditions such as a/c use, extra load, and trailer towing.

The multiplicative fuel volatility exhaust correction factor for LDFG is the same as for LDGV. The gasoline RVP correction is neutral for RVP less or equal to 9.0 psi. Considering that M85's vapor pressure is relatively low (RVP=8.0 psi for Gabele's M85), there is no fuel volatility correction for LDFM exhaust. Neither one of the LDF vehicle classes have an open loop correction, they are assumed to have closed loop technology, like Gabele's FFV.

Finally, the emission rates are weighted by travel fraction and summed up over all model years to obtain the vehicle class composite emission factor.

Algorithm for LDF HC exhaust emissions:

EFEXHv = SUM {EXHHCiv}
EXHHCiv = BEFivp*SALHCFivp*RVPCFivp*TFiv
BEFivp = BASEEXivp*EXTCORivp*CH4CORiv+FOMTAMiv for mileage less or equal to 50,000:
BASEEXivp = ZPOINTvp+SLOPE1vp*VMTAGEiv for mileage above 50,000:
BASEEXivp = ZPOINTvp+SLOPE1vp*5+SLOPE2vp*ABOVE50iv

where is:

EFEXHv : composite HC exhaust emission factor of vehicle class v
EXHHCiv : HC exhaust emission factor for model year i of vehicle class v
BEFivp : exhaust emission rate for model year i of vehicle class v and pollutant p corrected for temperature and tampering
SALHCFivp : speed and optional adjustment correction factor for model year i of vehicle class v and pollutant p
RVPCFivp : fuel volatility correction for model year i of vehicle class v and pollutant p (equals 1.0 for LDFM)
TFiv : model year i's fraction of total vehicle class v VMT
BASEEXivp : uncorrected HC exhaust emission rate for model year i of vehicle class v and pollutant p
EXTCORivpt: temperature correction for model year i of vehicle class v and pollutant p at temperature t
CH4CORivt : non-methane portion of HC exhaust for model year i of vehicle class v at temperature t
FOMTAMivp : tampering offset for model year i of vehicle class v and pollutant p
ZPOINTvp : zero mile level for vehicle class v and pollutant p
SLOPE1vp : deterioration rate for vehicle class v and pollutant p for less or equal to 50,000 miles
VMTAGEiv : accumulated mileage for model year i of vehicle class v
SLOPE2vp : deterioration rate for vehicle class v and pollutant p above 50,000 miles
ABOVE50iv : accumulated mileage above 50,000 miles for model year i of vehicle class v

Hydrocarbon evaporative losses

Evaporative emissions consist of three components: Hot soak emissions are evaporating fuel from either the carburetor system (carbureted vehicles) or from the fuel tank (fuel-injected vehicles) at the end of each trip. Diurnal emissions result from increases of ambient temperatures during the diurnal temperature cycle. The air-fuel mixture in a partially filled fuel tank expands and additional fuel vapor is generated and released into the atmosphere. Crankcase emissions come from the crankcase when the engine is running.

MOBILE4 calculates hot soak diurnal, and crankcase emissions for all gasoline vehicle classes and for motorcycles. Hot soak and diurnal emissions are the sum of excess RVP effect, RVP dependent malmaintenance and defect effect, FTP standard levels, and insufficient capacity effect. In UNCMOBILE4, evaporative emissions are determined for the two FFV classes in the same way.

The FTP condition base emission rates (g) for hot soak and diurnal emissions are obtained from Gabele (1990). The excess RVP effect and the malmaintenance and defect effect are figured by linear or quadratic equations using the same equation parameters as for 1981+ port fuel injected LDGV and the insufficient capacity effect is also zero. For LDFM, the weathered M85 RVP is applied in the equations, for LDFG the gasoline RVP. The effects are then normalized so that they yield the same portion of uncorrected rates as for LDGV.

The multiplicative offset to correct for deviating temperatures is figured by 2-point interpolation in function EVTCOR, based on Gabele's evaporative emission tests at 40, 75, and 90 F. Crankcase emissions are assumed to be zero for FFV since they are expected to have crankcase emission controls. If the user requests, hot soak and diurnal rates are also corrected for tampering. The offset is additive and yields the same portion of the untampered emission factor as for port fuel injected LDGV of the same model year.

The rates, still in units of grams per test are converted to weighted emission factors in g/mile by applying the same vehicle-age specific values for trips per day and miles per day as for LDGV. They are subsequently weighted by travel fraction and summed up over all model years to obtain the vehicle class composite emission factor.

Algorithm for LDF evaporative emissions:

EFEVAPv	= SUM {CCEVRTiv*TFiv}
CCEVRTiv	= [(HSiv*TPDiv+DUiv)/MPDiv]
HSiv	= (EVLDFeiv+EXev+DMev)*EVTCORevt+HSTAMi
DUiv	= (EVLDFeiv+EXev+DMev)*EVTCORevt+DUTAMi

where is:

EFEVAPv	: composite evaporative emission factor of vehicle class v
CCEVRTiv	: evaporative emission factor for model year i of vehicle class v
TFiv	: model year i's fraction of total vehicle class v VMT
HSiv	: hot soak emissions for model year i of vehicle class v
DUiv	: diurnal emissions for model year i of vehicle class v
EVLDFeiv	: evaporative base emission rate under FTP conditions for evaporative type e (hot soak or diurnal) and model year i of vehicle class v
EXev	: excess RVP effect on evaporative type e for vehicle class v
DMev	: malmaintenance and defect effect on evaporative type e for vehicle class v
EVTCORevt	: multiplicative temperature correction for evaporative type e and vehicle class v at temperature t
HSTAMi	: hot soak tampering offset for model year i
DUTAMi	: diurnal tampering offset for model year i

Hydrocarbon refueling losses

Refueling emissions, also termed Stage II emissions, consist primarily of displacement losses during vehicle refueling when the gasoline vapor in the fuel tank is displaced by incoming fuel. A lesser amount of vapor is released into the atmosphere due to spillage and subsequent evaporation. Refueling losses can be considerable. "EPA estimates that vehicle refueling emissions account for approximately two percent of the overall inventory of HC emissions in urban areas". Refueling emissions can be limited by either Stage II vapor recovery systems (VRS) at the service station, or onboard VRS. [EPA, 1989]

In MOBILE4, refueling losses are calculated for LDGV/T and HDGV. Constant grams per gallon (gpg) values are given for displacement and spillage. The vehicle class/model year emission factors are a function of the vehicles fuel economies, efficiencies of the vapor recovery systems, and the onboard VRS tampering rates.

The algorithm for LDF in UNCMOBILE4 is virtually the same as for the other vehicle classes. The emission factors for each vehicle class/model year group can be calculated for all five settings of flag RLFLAG. For the LDFM calculation, it is assumed that refueling M85 results in the same (gpg) displacement and spillage losses as refueling gasoline. This assumption seems reasonable at least for the spillage losses. There is no switch to in-use RVP for LDFM, that is the user-supplied RVP for M85 is not dependent on the evaluation year as it might be for gasoline vehicles.

If the user requests onboard VRS tampering to be considered for either one or both LDF classes and an onboard vrs is required for the model year, a vehicle-age dependent, multiplicative offset is applied. The offset yields the same as for LDGV and is corrected for the effects of an anti-tampering program (ATP) if there is one for the evaluation year. The vehicle class/model year emission factors are subsequently weighted by travel fraction and summed up to yield the vehicle class composite emission factor.

Algorithm for LDF refueling loss emissions:

EFLOSSv = SUM {RLRATEiv*TFiv}

for RLFLAG=1: uncontrolled emission rates for all model years:
RLRATEiv = (DISPL+SPILL)/ROADFEiv

for RLFLAG=2: Stage II VRS requirement:
RLRATEiv = (S2LEFTv*DISPL+SPILL)/ROADFEiv

for RLFLAG=3: onboard VRS requirement:
RLRATEiv = (1-(1-HTOBiv)*OBED)*DISPL+OBES*SPILL)/ROADFEiv

for RLFLAG=4: both Stage II and onboard VRS requirements:
Calculation like for only onboard control.

for RLFLAG=5: zero-out refueling emissions:
in this case, Stage II emissions are considered to be stationary sources.

where is:
EFLOSSv : composite refueling loss emission factor of vehicle class v
RLRATEiv : refueling loss emission factor (g/mile) for model year i of vehicle class v
TFiv : model year i's fraction of total vehicle class v VMT
DISPL : displacement component (grams per gallon)

SPILL : spillage component (grams per gallon). Both DISPL and SPILL are assumed to be the same for gasoline and M85.
ROADFEiv : road fuel economy rates (mpg) for model year i of vehicle class v
S2LEFT : portion of gasoline pumped that has Stage II controls applied
HTOBiv : onboard vrs tampering offset for model year i of vehicle class v
OBED : onboard vrs displacement loss efficiency
OBES : onboard vrs spillage loss efficiency. OBED and OBES are assumed to be the same for all 6 vehicle classes

Hydrocarbon running losses

Running loss emissions are evaporative emissions occurring while the vehicle is driven. They seem to result from insufficient evaporative canister purging during vehicle operation. When the canister reaches saturation and more fuel evaporates due to fuel tank temperature increase, these vapors are released into the atmosphere. Also fuel system leaks and other sources may contribute to the running loss emissions.

EPA test programs have shown that running loss HC emissions are considerable at the lower speeds representative of urban driving when less canister purging occurs, but very low at highway speeds. They have been determined to be a non-linear function of temperature, fuel volatility, and average speed. Other factors are vehicle type, vehicle age, and the evaporative control system. The tests were conducted for three different driving cycles, each representing a different average speed, at several different temperatures and fuel volatilities.

In MOBILE4, running loss emission factors are calculated for LDGV/T and HDGV. Diesel vehicles and motorcycles are assumed to generate no running loss emissions. UNCMOBILE4 determines running losses for each model year group of LDFM and LDFG in the same way as for the other vehicle classes.

The emissions are modeled by 4-point interpolation as a function of running loss temperature and running loss (weathered) fuel volatility. Due to insufficient data, they are not yet modeled as dependent on vehicle speed. The base emission factors used in MOBILE4 are composites of the results of the three driving cycle tests, weighted on the basis of urban travel characteristics. Model year and vehicle age dependent correction factors, also determined by 4-point interpolation, are applied for canister disconnect and gas cap tampering.

Since Gabele did not supply running loss data, the base emission rates as a function of RVP and temperature for LDF are the same as for 1981+ LDGV. The underlying assumption is that, given the same RVP and temperature, M85 and gasoline produce the same amount of running loss emissions. For LDFM applies the user specified RVP of M85, after lowered somewhat to account for weathering, whereas for LDFG the gasoline RVP applies.

If user requested, the running loss emission factors are also corrected for canister disconnect and gas cap removal tampering. The multiplicative offsets are the same as for LDGV of the same model year and includes the effects of an ATP if there is one for the evaluation year.

Algorithm for LDF refueling loss emissions:

EFRUNLv = SUM {RNGLOSiv*TFiv}
RNGLOSiv = RULOSSiv*FCANOFi*FCAPOFi

where is:

EFRUNLv	: composite running loss emission factor of vehicle class v
RNGLOSiv	: running loss emission factor (g/mile) for model year i of vehicle class v
TFiv	: model year i's fraction of total vehicle class v VMT
RULOSSiv	: untampered running loss rate for model year i of vehicle class v, calculated by 4-point interpolation
FCANOFi	: canister disconnect tampering offset
FCAPOFi	: gas cap removal tampering offset

CO and NOx exhaust emissions

CO and NOx exhaust emission rates are modeled very similar to HC exhaust emissions. They are calculated for all vehicle classes depending on vehicle mileage, temperature, tampering effects, speed, location-specific adjustments, and the fuel's RVP. The uncorrected base emission rate for each model year/vehicle class group is calculated using zero mile emission level (zml) from Gabele's FFV tests under FTP conditions. The deterioration rates yield the same portion of the pollutants zml as for 1993 model year LDGV. The CO emissions have higher dr above 50,000 miles. Zml and dr are the same for both low and high altitude and constant for all model years.

The temperature correction factor used is also determined by 2-point interpolation based on Gabele's tests for 40, 75, and 90 F. If user-requested, an additive tampering offset is utilized that yields the same portion of the non-tampered emission factor as for the LDGV of that model year and that includes the effect of an anti-tampering program if one applies for the evaluation year. The LDGV correction factor for a speed deviating from the FTP average speed and for optional location-specific conditions is also applied.

LDFG CO and NOx exhaust emission factors have the same multiplicative fuel volatility correction as LDGV and there is no fuel volatility correction for LDFM exhaust. LDF CO and NOx calculations have no open loop correction. The emission rates are finally weighted by travel fraction and summed up to obtain the vehicle class composite emission factor.

Algorithm for LDF CO and NOx exhaust emissions:

EFFTPvp	= SUM {COMPEFivp}
COMPEFivp	= BEFivp*SALHCFivp*RVPCFivp*TFiv
BEFivp	= BASEEXivp*EXTCORivpt+FOMTAMivp for mileage less or equal to 50,000:
BASEEXivp	= ZPOINTvp+SLOPE1vp*VMTAGEiv for mileage above 50,000:
BASEEXivp	= ZPOINTvp+SLOPE1vp*5+SLOPE2vp*ABOVE50iv

where is:

EFEXHvp	: composite exhaust emission factor of vehicle class v and pollutant p
COMPEFivp	: exhaust emission factor for model year i of vehicle class v and pollutant p
BEFivp	: exhaust emission rate for model year i of vehicle class v and pollutant p corrected for temperature and tampering
SALHCFivp	: speed and optional adjustment correction factor for model year i of vehicle class v and pollutant p
RVPCFivp	: fuel volatility correction for model year i of vehicle class v and pollutant p (equals 1.0 for LDFM)
TFiv	: model year i's fraction of total vehicle class v VMT
BASEEXivp	: uncorrected exhaust emission rate for model year i of vehicle class v and pollutant p
EXTCORivpt	: temperature correction for model year i of vehicle class v and pollutant p at temperature t
FOMTAMivp	: tampering offset for model year i of vehicle class v and pollutant p
ZPOINTvp	: zero mile level for vehicle class v and pollutant p
SLOPE1vp	: deterioration rate for vehicle class v and pollutant p for less or equal to 50,000 miles
VMTAGEiv	: accumulated mileage for model year i of vehicle class v
SLOPE2vp	: deterioration rate for vehicle class v and pollutant p above 50,000 miles

ABOVE50iv : accumulated mileage above 50,000 miles for model year i of vehicle class v

4.2 USER'S GUIDANCE FOR UNCMOBILE4

As in MOBILE4, the user determines by the setting of the PROMPT flag whether he will be prompted for the remainder of the input stream or whether he supplies a prepared, formatted input file. In order to obtain emission factors for methanol cars, the user sets METFLG, the very last flag of the control section to 2. If he does not want to include methanol cars, METFLG is to set to 1. If METFLG's setting is 2, the user is required to supply information on the FFV fleet at the very end of the one-time input section. Six additional input records referring to methanol cars are required. An UNCMOBILE4 example input is shown in Appendix A.

A. FFV sales fractions

The first two records contain information on the annual sales shares of Light Duty Flexible fueled vehicles from model year 1993 onward. The numbers required are the flexible fueled cars fraction of total light duty vehicles (gasoline, diesel, and FFV) sold. The first record covers the model years 1993 through 2002, the second one 2003 through 2012. Like light duty gasoline cars, FFV model year sales are assumed to start in October, that is the model year sales are those from 10/(my-1) through 9/my. The FFV sales fractions for model years before 1993 are assumed to be zero, for model years 2013+ to equal those of 2012. The format for record one and two is (10F6.4).

B. Fraction of FFV running on M85

This record contains information on the fraction of FFV running on M85, that is the fraction of vehicle miles travelled (VMT) actually using M85 in the evaluation year. The format is (F6.4).

C. Fuel volatility of M85

This record contains the Reid Vapor Pressure (psi) of the utilized M85. The value can be anywhere between 7.0 and 15. psi. The format is (F4.1).

D. Control flag for LDFM calculation

MCHOS1, the flag controlling the emission factor calculation for Light Duty Flexible fueled vehicles running on Methanol (LDFM) can be set to 1 or 2. If MCHOS1 equals 1, the LDFM emission factors do not include the effects of tampering. If MCHOS1 equals 2, the LDFM emission factors include the impact of tampering accordingly to Light Duty Gasoline Vehicles (LDGV). For each model year/pollutant group, the LDFM tampering effect yields the same portion of the untampered emission factor as for LDGV of the same model year. That is, the relative effect of tampering is assumed to be the same for both vehicle classes. The input format is (I1).

E. Control flag for LDFG calculation

MCHOS2, the flag controlling the emission factor calculation for Light Duty Flexible fueled vehicles running on Gasoline (LDFG) can be set to 1, 2, or 3. If MCHOS2 equals 1, the LDFG emission factors do not include the effects of tampering. If MCHOS2 equals 2, the LDFG emission factors include the impact of tampering. For each model year/pollutant group, the LDFG tampering effect yields the same portion of the untampered emission factor as for LDGV of the same model year. That is, the relative effect of tampering is assumed to be the same for both vehicle classes. For MCHOS2 equal to 3, all LDFG model year/pollutant emission factors are assumed to be the same as for LDGV. This opportunity is given since LDFG and LDGV emissions are usually assumed to be the same. The input format is (I1).

Some restrictions apply for UNCMOBILE4's optional user input:

The user should not supply any of the optional input specified below: VMT mix (VMFLAG), annual mileage accumulation rates and registration distributions (MYMFLG), basic exhaust emission rates (NEWFLG). OUTFMT's only valid setting is 4 because the 94-column descriptive output is the only one adjusted to UNCMOBILE4. IDLFLG needs to set to 1, no idle emissions can be calculated for LDF yet.

If the user supplies tampering rates (TAMFLG=2), different speeds for the eight vehicle types (SPDFLG=2), inspection/maintenance programs (IMFLAG=2), optional corrections for A/C, extra load, trailer towing, and humidity (ALHFLG=2 or 3), or anti-tampering program (ATPFLG=2), the LDGV rates also apply for LDF.

REFLAG, the flag controlling refueling emissions can be set to all values. The user specifies whether onboard vapor recovery systems apply for LDF, and specified Stage II gasoline vrs parameter also apply for M85. Both settings of temperature correction flag (TEMFLG) can be applied, the specified temperature calculation applies also to LDF. RVP information supplied in the local area parameter record only applies to gasoline. All flag settings are permitted for PROMPT, PRTFLG, NMHFLG, and HCFLAG.

4.3 Performance of UNCMOBILE4

An example output of UNCMOBILE4 is shown in Appendix B. A scenario is evaluated in which M85 is introduced and LDFM are the predominant light duty vehicle class. The first portion of the output echoes the user input associated with methanol cars. In this scenario, the sales fractions of FFV increase from 5% in 1993 to 95% in 2001 and stay constant after that. 905 of the FFV actually run on M85. The Reid Vapor pressure of M85 is 8 psi, as it is for Gabele's test M85 fuel. The calculations for both vehicle classes include tampering.

The next section of the output shows other user input such as the evaluation year 2013. The user-specified average speed is 25 mph. As can be seen by looking at the VMT shares, the LDFM make up the greatest portion of the fleet. They account for 57.7% of total miles driven, whereas the share of LDGV went down to 7.9%. Finally, the emission factors are displayed, for each vehicle class/pollutant combination as well as the composite fleet emission factors.

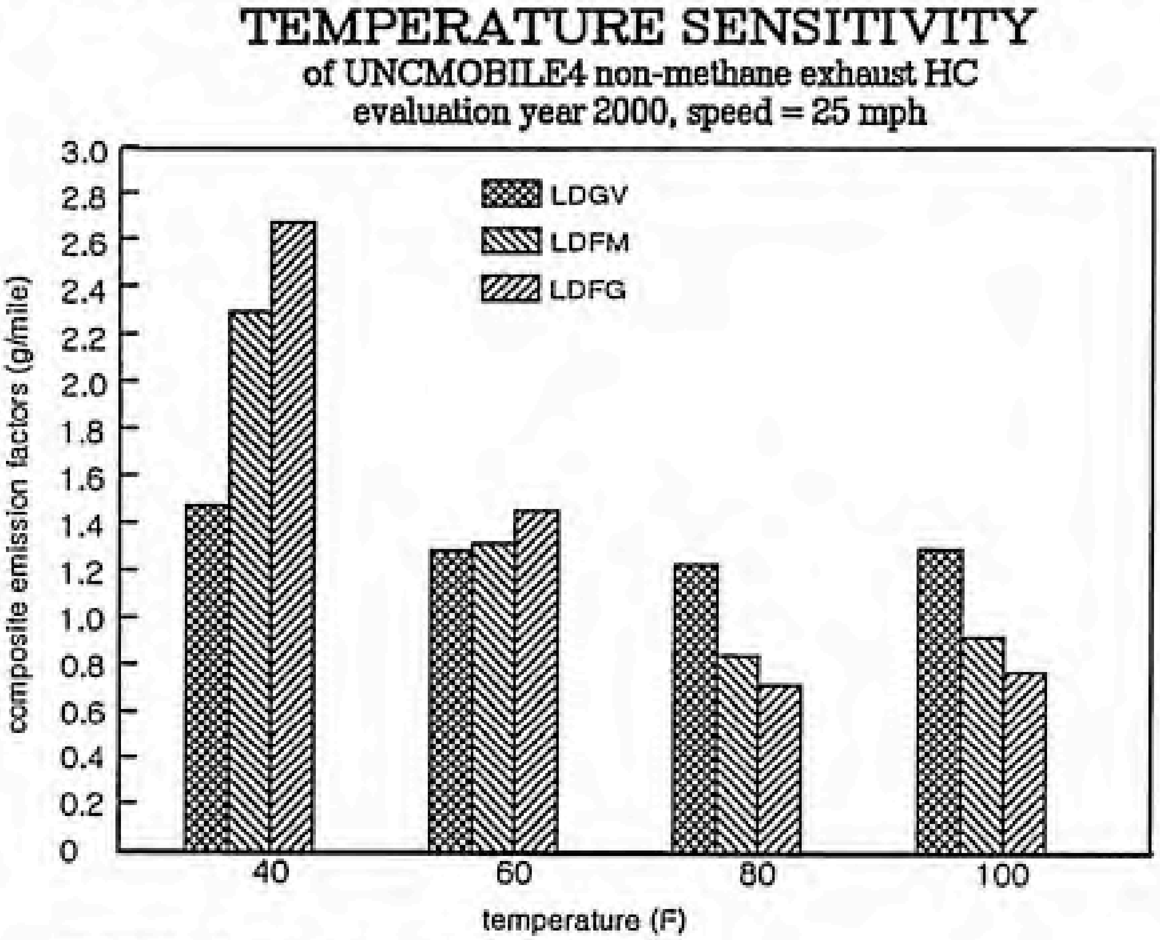

FIGURE4: Temperature sensitivity

The sensitivity of UNCMOBILE4's output emission factors for temperature and evaluation year is shown in FIGURE4 and FIGURE5. They also illustrate differences between the three light duty vehicle classes. The scenario described above is run while varying only temperature and evaluation year for FIGURE4 and FIGURE5, respectively.

FIGURE4 shows HC exhaust emissions of LDGV, LDFM, and LDFG as a function of temperature. LDF's exhaust emissions appear to be more temperature sensitive than those of LDGV. The winter mass emissions are higher for FFV, whereas the summer emissions, important for the ozone issue, are shown to be higher for LDGV. For high temperatures, the HC mass emissions of LDFG are modelled to be lowest, but it needs to be considered that their composition is expected to be less favorable than of those from LDFM.

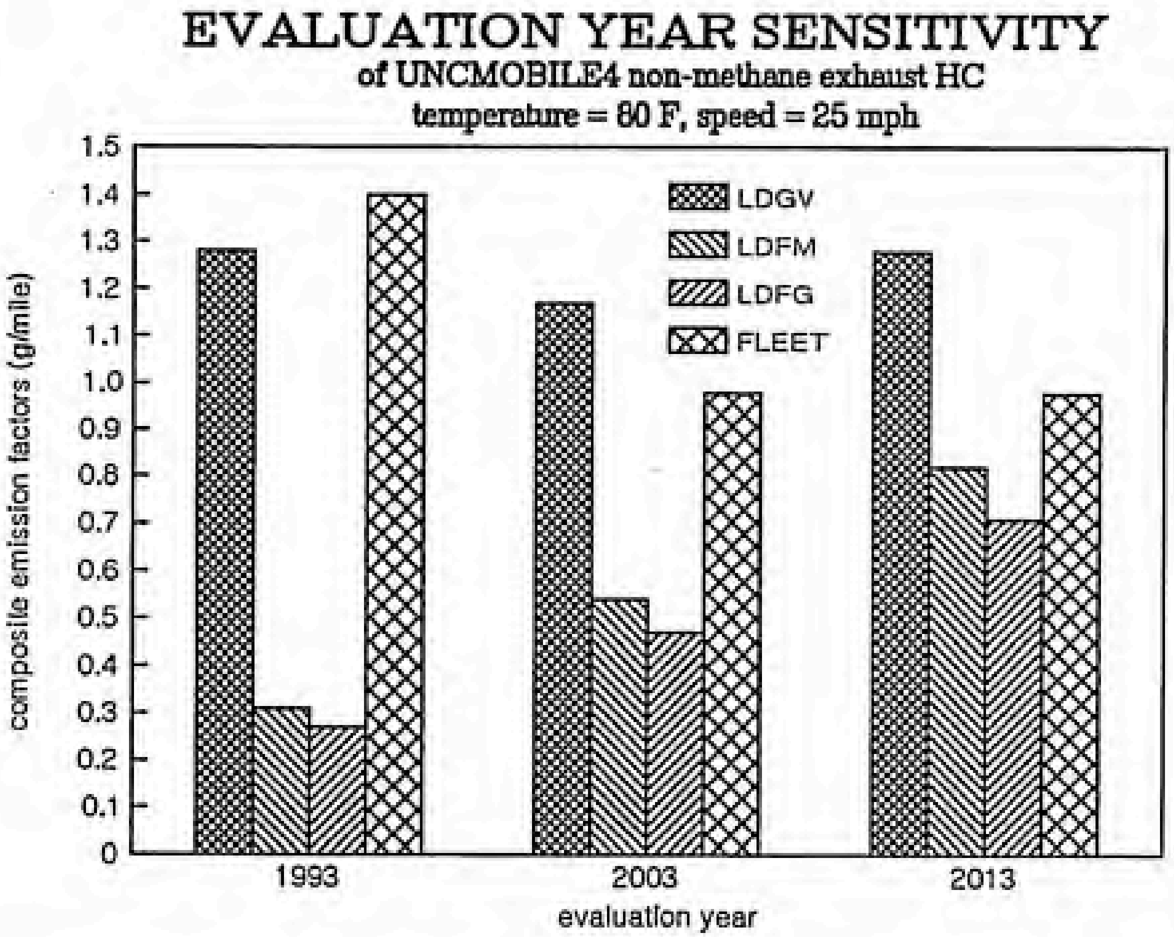

FIGURE5: Evaluation year sensitivity

FIGURE 5 illustrates the development of HC exhaust emissions, for LDGV, LDFG, and LDFM as well as the fleet composite emissions. In 1993, LDF are all newest model year, therefore they show very low emission factors and almost no deterioration. The fleet emissions are still dominated by LDGV which include many old cars, build for higher emission standards. In 2003, the LDGV become in average somewhat cleaner since old cars with higher standards are phased out. LDF emissions increase due to the increasing average age of the LDF. In 2013, the age of the LDF fleet and therefore also their emission factors increased further. The composite fleet emission factors are now dominated by LDFM, the largest vehicle class.

5. Recommendations for Further Changes of UNCMOBILE4

UNCMOBILE4 does not yet provide reliable emission factors for flexible fueled cars since the data currently utilized is not based on the most advanced technology, and is not necessarily representative for a future FFV fleet. Furthermore many assumptions underlying the numerous correction factor calculations are adopted unchecked from light duty gasoline cars. Considering M85's low volatility, particularly RVP effects should be checked against test results. Also those of speed, temperature, and driving mode, should be proved in order to refine the calculations. The mass emission rates of FFV running on gasoline will have to be investigated whether they can be assumed to be the same as for conventional light duty vehicles.

If once released, methanol car data from the Auto/Oil study could supply the test data basis to refine UNCMOBILE4's emission factor calculations. This extensive, well-funded research program is initiated by three domestic auto companies and fourteen petroleum companies. Its objective is to develop data for use by regulators on the potential benefits from reformulated gasoline, various other alternative fuels, and developments in automobile technology on vehicle emissions and air quality, primarily focussed on ozone.

Auto/Oil examines exhaust, evaporative, and running loss emissions from current and older vehicles. It provides detailed data on mass and composition (151 species) of organic emissions and on mass of CO and NOx emissions. The data is also specified for the three FTP driving modes cold start, hot stabilized, and hot start and for the idle mode. Flexible and Variable Fuel vehicles are examined for several methanol/gasoline blends, including two slightly differing M85 blends.

The data on M85 emissions will have to be checked to see whether it is representative for a future FFV fleet, for instance in terms of engine size and fuel economy. Appropriate adjustments might have to be conducted. The current UNCMOBILE4 base emission rates for exhaust, evaporative, and running loss emissions can then be replaced.

If Auto/Oil provides test results for different temperatures and speeds, those can be inserted for the current base for correction factor calculations. Auto/Oil's two M85 fuels have virtually the same RVP (8.6 and 8.8 psi), thus this data can not be utilized to determine the impact of fuel volatility. If the data contains information on in-use deterioration rates for FFV, those can be utilized instead of the LDGV-like deterioration rates used now.

Auto/Oil will not provide any data on tampering. Considering proposed FFV technology, detailed estimates will have to be made about expected tampering effects and rates and about possible benefits from inspection/maintenance and anti-tampering programs, based on those impacts for LDGV.

UNCMOBILE4, once refined by using the research results from Auto/Oil, will have to be checked against emission rates from in-use methanol vehicles. On-road measurements such as tunnel studies could finally validate its emission factor output. So it could be made reliable enough to be the basis for the important and costly decision on wether or not to utilize methanol fuels.

Useful further changes to the program structure are: fully including LDF in the optional Onetime user input, allowing the use of all four output formats, and allowing methanol car evaluation for more than one scenario.

6. BIBLIOGRAPHY

Auto/Oil Air Quality Improvement Research Program: Technical Bulletin No. 1 - Initial Mass Exhaust Emissions from Reformulated Gasolines, 1990

Dunker, A.: "Relative Reactivity of Emissions from Methanol and Gasoline Fueled Vehicles in Forming Ozone", Environmental Science and Technology, Volume 24,No.6, 1990, pp.853-862

Environmental Protection Agency: User's Guide to MOBILE4 (Mobile Source Emission Factor Model), Ann Arbor, Michigan, 1989

Environmental Protection Agency: Programmer's Guide to MOBILE4 (Mobile Source Emission Factor Model), Ann Arbor, Michigan, 1989

Environmental Protection Agency: Compilation of Air Pollutant Emission Factors - Volume II: Mobile Sources (4th Edition), Ann Arbor, Michigan, 1985

Environmental Protection Agency: Supplement A to Compilation of Air Pollutant Emission Factors - Volume II: Mobile Sources, Ann Arbor, Michigan, 1991

Environmental Protection Agency: MOBILE4 Oxygenated Fuels Version User's Guide, Ann Arbor, Michigan, 1989

Environmental Protection Agency: Guidance on Estimating Motor Vehicle Emission Reductions from the Use of Alternative Fuels and Fuel Blends, Ann Arbor, Michigan, 1988

Environmental Protection Agency: Analysis of the Economic and Environmental Effects of Methanol as an Automotive Fuel, 1989

Gabele, P.: "Characterization of Emissions from a Variable Gasoline/Methanol Fueled Car", Journal of Air and Waste Management Association, Volume 4, No.3, 1990, pp. 296-304

Gabele, P.,Knapp, K.: "A Characterization of Emissions from an Early Model FFV", Air and Waste Management Association Paper 91-106.6, June 1991

Jeffries, H., Charles, J.,Sexton, K.: Fundamental and Practical Studies of Reactivities of Alternative Fuels - Draft, Chapel Hill, 1991

Seinfeld, J.: "Ozone Air Quality Models - A Critical Review", Journal of the Air Pollution Control Association, Volume 38, No.5, 1988, pp. 616-645

APPENDIX A: UNCMOBILE4 Example Input

```
1                                                 PROMPT
UNCMOBILE4 Example Run
1                                                 TAMFLG
1                                                 SPDFLG
1                                                 VMFLG
1                                                 MRMYFG
1                                                 NEWFLG
1                                                 IMFLAG
1                                                 ALHFLG
1                                                 ATPFLG
1                                                 RLFLAG
1                                                 LOCFLG
1                                                 TEMFLG
4                                                 OUTFMT
4                                                 PRTFLG
1                                                 IDLFLG
2                                                 NMHFLG
2                                                 HCFLG
2                                                 METFLG
0.050 0.100 0.150 0.200 0.300 0.500 0.700 0.900 0.950 0.950
0.950 0.950 0.950 0.950 0.950 0.950 0.950 0.950 0.950 0.950
0.900
8.0
2
2
1 13 25.0 80.0 20.6 27.3 20.6
Atlanta       GA C  71.0  86 11.5 11.5 20
```

APPENDIX B: UNCMOBILE4 Example output

UNCMOBILE4 Example Run

Light Duty Flexible Fueled Vehicles are evaluated:

The flexible fueled cars fractions of total Light Duty Vehicles sold
for model years 1993 through 2012+ are:

0.050	0.100	0.150	0.200	0.300	0.500	0.700	0.900	0.950	0.950
0.950	0.950	0.950	0.950	0.950	0.950	0.950	0.950	0.950	0.950

The fraction of flexible fueled cars running on M85 is:
0.90

The Reid Vapor Pressure (psi) of the M85 is:
8.0

LDFM output emission factors include tampering.
LDFG output emission factors include tampering.

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

Cal. Year: 2013 Region: Low Altitude: 500. Ft.
I/M Program: No Ambient Temp: 82.8 / 82.8 / 82.8 F
Anti-tam. Program: No Operating Mode: 0.0 / 0.0 / 20.6

Atlanta GA ASTM Class: C
Minimum Temp: 71. (F) Maximum Temp: 86. (F)
Base RVP: 11.5 In-use (IU) RVP: 11.5 IU 1st Yr: 2020

Veh. Type:	LDGV	LDGT1	LDGT2	LDGT	HDGV	LDDV	LDDT	HDDV	MC	LDFM	LDFG	All Veh
Veh. Spd.:	25.0	25.0	25.0		25.0	25.0	25.0	25.0	25.0	25.0	25.0	
VMT Mix:	0.079	0.113	0.087		0.015	0.004	0.021	0.029	0.010	0.577	0.064	
Composite Emission Factors (Gm/Mile)												
No-Mth HC:	3.63	2.67	2.74	2.70	5.65	0.53	0.56	1.68	4.75	1.72	2.53	2.18
Exhst HC:	1.28	1.23	1.30	1.26	1.73	0.53	0.56	1.68	1.56	0.82	0.71	0.98
Evap. HC:	0.73	0.50	0.49	0.50	1.47				3.19	0.07	0.31	0.27
Refuel HC:	0.25	0.33	0.33	0.33	0.52					0.41	0.25	0.34
Runing HC:	1.38	0.61	0.63	0.62	1.93					0.43	1.27	0.59
Exhst CO:	20.38	18.46	19.41	18.87	27.58	1.26	1.24	8.35	17.94	6.55	6.03	10.43
Exhst NOX:	1.20	1.28	1.28	1.28	4.41	1.13	1.13	7.37	0.89	0.40	0.34	0.92

APPENDIX C: SUBROUTINE EFCALX

```
      SUBROUTINE EFCALX(ICY,INERR)
C
C Calculates composite emission factors.
C
      CHARACTER*4 SCNAME
      CHARACTER*1 ASTMCL,ACLASS
      INTEGER ATPFLG,TPDFLG,RLFLAG,TEMFLG,OUTFMT
      INTEGER PRTFLG,HCFLAG
      REAL JULMYR,JANMYR
      COMMON /CITCIN/ UDI(5),IUDI,CIGAS1,CIGAS2,CIETH1,CIETH2,ICERSW
      COMMON /CITPAR/ SCNAME(4),FRETH,FRMETH,FRGAS
      COMMON /CITRV3/ RVPMAP(5),RVPX(2,2),ICLASS,ASTMCL,ACLASS(5)
      COMMON /CUMCOM/ CUMMIL(20,10)
      COMMON /EGSCAL/ AER(11,11,2,2),TGS(11,6,4),EGS(7,2),OPENLP(20,4)
      COMMON /FLAGS3/ ATPFLG,TPDFLG,RLFLAG,LOCFLG,TEMFLG,OUTFMT
      COMMON /FLAGS4/ PRTFLG,IDLFLG,NMHFLG,HCFLAG,METFLG
      COMMON /GSFCOM/ MAXGSF,GSFRAC(22,10,2),MYGSF(22,10,2)
      COMMON /MAXIMA/ MAXVEH,MAXLTW,MAXPOL,MAXREG,MAXYRS
      COMMON /MYRCAL/ XMYM(20,10),JANMYR(20,10),TF(20,10),TFMYM(20,10)
      COMMON /MYRSAV/ AMAR(20,10),JULMYR(20,10),NEWCUM
      COMMON /REGION/ FEET(2),IREJN,ALT,INITPR
      COMMON /RESUL1/ EFFTP(3,11),EFEXH(11),EFEVAP(11),EFLOSS(11),
     *                  EFRUNL(11)
      COMMON /RESUL3/ VFTP(3),VEXH,VEVAP,VLOSS,VRUNLS,VIDLE(3)
      COMMON /RVPEX2/ MYGRVP(4,4),RVPCF(20,3,4,2),OPENCR
      COMMON /SPEED6/ SALHCF(20,3,8),HSLHCF
      COMMON /VMXCOM/ REGMIX(10),TFNORM(10),VMTMIX(10)
      COMMON /FFVCOM/ MAXMSF,FFVFRA(21),MYMSF(21),METFRA,RVPM85,INRVPM,
     *                RVPMLS,MCHOS1,MCHOS2
      IF(NEWCUM.NE.0) CALL GETCUM(ICY)
      NEWCUM=0
      VMLDGT=VMTMIX(2)+VMTMIX(3)
      IF(VMLDGT.EQ.0.0) VMLDGT=1.
C
C Calculate tampering offsets, refueling losses, RVP correction,
C and optional correction factors.
C
      CALL TAMPER(ICY)
      IF(PRTFLG.EQ.1.OR.PRTFLG.EQ.4) CALL REFUEL(ICY)
      CALL RVPEXH(ICY,1,RVPX(1,1),RVPX(2,1))
      IF(FRETH.GT.0.0) CALL RVPEXH(ICY,2,RVPX(1,2),RVPX(2,2))
C
C BIGCFX gets correction factors for speed, temperature, operating mode
C tampering , air conditioning, trailer towing, humidity, extra load,
C and by-bag RVP. These correction factors depend on the usere's input.
C
      CALL BIGCFX(ICY)
C
C Calculate idle emissions.
```

```
C
      IF(IDLFLG.EQ.2) CALL IDLCAL(ICY,VMLDGT,INERR)
C
C Calculate HC emission factors.
C
      IF(PRTFLG.EQ.1.OR.PRTFLG.EQ.4)
     *     CALL HCCALX(ICY,VMLDGT,INERR)
C
C Calculate CO and NOx FTP emission factors.
C Start loop through pollutant classes CO and NOx.
C
      DO 70 IP=2,MAXPOL
      IF(PRTFLG.NE.IP.AND.PRTFLG.NE.4) GOTO 70
      VFTP(IP)=0.0
      EFFTP(IP,11)=0.0
C
C Start loop through vehicle classes.
C
      DO 60 IV=1,10      !10 for MAXVEH
      EFFTP(IP,IV)=0.0
      IF(VMTMIX(IV).EQ.0.0) GOTO 60
C
C Start loop through model years.
C
      DO 50 IDX=1,MAXYRS
      IF(TF(IDX,IV).LE.0.0) GOTO 50
      COMPEF=0.0
      JDX=21-IDX
      VMTAGE=CUMMIL(JDX,IV)/10000.
      MY=ICY+IDX-20
C
C JHELP is the model year group pointer to the gas/diesel sales fractions.
C
      IGS=JHELP(MY,IV)
C
C SALHCF is the multiplicative correction factor for speed and optional
C adjustments (a/c, extra load, trailer towing, humidity). For LDFM and
C LDFG, SALHCF is assumed to be the same as for LDGV. All parameters of
C the speed correction equations are constant for 1992+ anyway.
C
      HSLHCF=SALHCF(IDX,IP,IV)
      IF(IV.EQ.9.OR.IV.EQ.10) HSLHCF=SALHCF(IDX,IP,1)
      EXHWGT=HSLHCF*TF(IDX,IV)
C
C IBEFSW is set to 2, so that BEF performs the operating mode corrections.
C BEF returns the corrected basic emission factors.
C
      IBEFSW=2
      COMPEF=BEF(MY,IDX,ICY,IP,IV,VMTAGE,IBEFSW)*EXHWGT
C
C MC have no RVP exhaust cf, but get CO open loop technology credit.
C Composite ef is complete for diesel and MC.
```

```
C
      IF(IV.EQ.8.AND.IP.NE.3)
     *    COMPEF=COMPEF*(FRGAS+(FRETH+FRMETH)*(1.0-OPENCR))
      IF(IV.GE.5.AND.IV.LE.8) GOTO 40
C
C LDGV/T, HDGV, and LDFG exhaust NOx ef have an multiplicative RVP cf, but no
C open loop technology credit. LDFM exhaust NOx ef have no open loop technology
C credit and are assumed to be independent of M85's RVP.
C
      IF(IV.EQ.9.AND.IP.EQ.3) GOTO 40
      IF(IV.EQ.10.AND.IP.EQ.3) THEN
         COMPEF=COMPEF*RVPCF(IDX,IP,1,1)
      ELSE
        IF(IP.EQ.3) COMPEF=COMPEF*RVPCF(IDX,IP,IV,1)
      END IF
      IF(IP.EQ.3) GOTO 40
C
C LDGV/T and HDGV CO ef both have RVP exhaust and open loop technology
C cf. LDFG CO ef have no open loop technology credit, but gasoline RVP
C correction. LDFM CO ef have no open loop technology credit and are
C assumed to be independent of M85's RVP.
C
      OPENRE=1.0-OPENLP(IDX,IV)*OPENCR
      RVOPCF=FRGAS*RVPCF(IDX,IP,IV,1)
     *     +(FRETH*RVPCF(IDX,IP,IV,2)
     *     +FRMETH*RVPCF(IDX,IP,IV,1))*OPENRE
      IF(IV.EQ.9) RVOPCF=1.0
      IF(IV.EQ.10) RVOPCF=RVPCF(IDX,IP,1,1)
      COMPEF=COMPEF*RVOPCF
C
C If the user sets MCHOS2=3, the LDFG model year CO and NOx ef for are the
C same as for LDGV.
C
   40 IF(IV.EQ.10.AND.IP.EQ.2.AND.MCHOS2.EQ.3.AND.MY.GE.1993)
     *        COMPEF=BEF(MY,IDX,ICY,IP,1,VMTAGE,IBEFSW)*EXHWGT*
     *        (1.0-OPENLP(IDX,1)*OPENCR)*RVPCF(IDX,IP,1,1)
      IF(IV.EQ.10.AND.IP.EQ.3.AND.MCHOS2.EQ.3.AND.MY.GE.1993)
     *        COMPEF=BEF(MY,IDX,ICY,IP,1,VMTAGE,IBEFSW)*EXHWGT*
     *        RVPCF(IDX,IP,1,1)
C
C Sum up to get weighted final ef for pollutant and vehicle class.
C
      EFFTP(IP,IV)=EFFTP(IP,IV)+COMPEF
C
C End model year loop.
C
   50 CONTINUE
      IF((IV.NE.4.AND.IV.LT.7).AND.
     *   (EFFTP(IP,IV).GT.0.0.AND.GSFRAC(IGS,IV,IREJN).EQ.0.0))
     *   CALL QUITER(0.,IV,67,INERR)
      IF(EFFTP(IP,IV).LE.0.0) CALL QUITER(0.,IV,68,INERR)
C
```

```
C Weight ef to get final ef for pollutants.
C
      VFTP(IP)=VFTP(IP)+EFFTP(IP,IV)*VMTMIX(IV)
C
C  End model vehicle classes loop.
C
   60 CONTINUE
      IF(EFFTP(IP,2).GT.0.0.AND.EFFTP(IP,3).GT.0.0) EFFTP(IP,11)=
     *   (EFFTP(IP,2)*VMTMIX(2)+EFFTP(IP,3)*VMTMIX(3))/VMLDGT
C
C  End model pollutant loop.
C
   70 CONTINUE
      RETURN
      END
```

APPENDIX D: SUBROUTINE HCCALX

```
      SUBROUTINE HCCALX(ICY,VMLDGT,INERR)
C
C Calculates HC emission factors.
C
      CHARACTER*4 SCNAME
      INTEGER ATPFLG,TPDFLG,RLFLAG,TEMFLG,OUTFMT
      REAL JANMYR
      COMMON /CITCIN/ UDI(5),IUDI,CIGAS1,CIGAS2,CIETH1,CIETH2,ICERSW
      COMMON /CITPAR/ SCNAME(4),FRETH,FRMETH,FRGAS
      COMMON /CITRV1/ RVPBAS,RVPIUS,RVPAST,RVPICY,RVPETH,IUSESY,RATUNC
      COMMON /CITRV2/ RVPHS1,RVPHS2,RVPET1,RVPET2,RVP090,RVP100,RVP115
      COMMON /CUMCOM/ CUMMIL(20,10)
      COMMON /EGSCAL/ AER(11,11,2,2),TGS(11,6,4),EGS(7,2),OPENLP(20,4)
      COMMON /EVAPGR/ EVP(4),GREVP(4,11),VGREVP(4)
      COMMON /FLAGS3/ ATPFLG,TPDFLG,RLFLAG,LOCFLG,TEMFLG,OUTFMT
      COMMON /GSFCOM/ MAXGSF,GSFRAC(22,10,2),MYGSF(22,10,2)
      COMMON /MAXIMA/ MAXVEH,MAXLTW,MAXPOL,MAXREG,MAXYRS
      COMMON /MYRCAL/ XMYM(20,10),JANMYR(20,10),TF(20,10),TFMYM(20,10)
      COMMON /RLCOM3/ RLRATE(20,10)
      COMMON /REGION/ FEET(2),IREJN,ALT,INITPR
      COMMON /RESUL1/ EFFTP(3,11),EFEXH(11),EFEVAP(11),EFLOSS(11),
     *                      EFRUNL(11)
      COMMON /RESUL3/ VFTP(3),VEXH,VEVAP,VLOSS,VRUNLS,VIDLE(3)
      COMMON /RVPEX2/ MYGRVP(4,4),RVPCF(20,3,4,2),OPENCR
      COMMON /SPEED6/ SALHCF(20,3,8),HSLHCF
      COMMON /VMXCOM/ REGMIX(10),TFNORM(10),VMTMIX(10)
      COMMON /FFVCOM/ MAXHSF,FFVFRA(21),MYHSF(21),METFRA,RVPM85,INRVPM,
     *                  RVPMLS,MCHOS1,MCHOS2
      DIMENSION EVPSUM(4)
      EFEXH(11)=0.0
      EFEVAP(11)=0.0
      EFLOSS(11)=0.0
      EFRUNL(11)=0.0
      VEXH=0.0
      VEVAP=0.0
      VLOSS=0.0
      VRUNLS=0.0
      DO 10 IEVP=1,4
      GREVP(IEVP,11)=0.0
      VGREVP(IEVP)=0.0
   10 CONTINUE
      IP=1
      EFFTP(IP,11)=0.0
      VFTP(IP)=0.0
C
C Start loop through vehicle classes
C
      DO 70 IV=1,10
      EFFTP(IP,IV)=0.0
```

```
      EFEXH(IV)=0.0
      EFEVAP(IV)=0.0
      EFLOSS(IV)=0.0
      EFRUNL(IV)=0.0
      DO 15 IEVP=1,4
      GREVP(IEVP,IV)=0.0
   15 CONTINUE
      IF(REGMIX(IV).EQ.0.0.AND.VMTMIX(IV).EQ.0.0) GOTO 70
C
C Start loop through years
C
      DO 55 IDX=1,MAXYRS
      JDX=21-IDX
      IF(TF(IDX,IV).LE.0.0.AND.JANMYR(JDX,IV).EQ.0.0) GOTO 55
      COMPEF=0.0
      EXHHC=0.0
      COMPCC=0.0
      GASCAP=0.0
      RNGLOS=0.0
      DO 20 IEVP=1,4
      EVPSUM(IEVP)=0.0
   20 CONTINUE
      VMTAGE=CUMMIL(JDX,IV)/10000.
      MY=ICY+IDX-20
      IGS=JHELP(MY,IV)
C
C First, calculation of exhaust HC.
C
C SALHCF is the multiplicative correction factor for speed and optional
C adjustments (a/c, extra load, trailer towing, humidity). For LDFM and
C LDFG, SALHCF is assumed to be the same as for LDGV. All parameters of
C the speed correction equations are constant for 1992+ anyway.
C
      HSLHCF=SALHCF(IDX,IP,IV)
      IF(IV.EQ.9.OR.IV.EQ.10) HSLHCF=SALHCF(IDX,IP,1)
      EXHWGT=HSLHCF*TF(IDX,IV)
      IBEFSW=2
      EXHHC=BEF(MY,IDX,ICY,IP,IV,VMTAGE,IBEFSW)*EXHWGT
C
C If the user sets MCHOS2=3, the LDFG model year HC exhaust ef are the
C same as for LDGV.
C
      IF(IV.EQ.10.AND.MCHOS2.EQ.3.AND.MY.GE.1993)
     *       EXHHC=BEF(MY,IDX,ICY,IP,1,VMTAGE,IBEFSW)*EXHWGT
C
C Exhaust HC emission factors for diesel are complete.
C
      IF(IV.GE.5.AND.IV.LE.7) GOTO 25
C
C Exhaust HC for MC are complete.
C
      IF(IV.EQ.8)
```

```
     *    EXHHC=EXHHC*(FRGAS+(FRETH+FRMETH)*(1.0-OPENCR))
      IF(IV.EQ.8) GOTO 25
C
C Exhaust HC emission factors for LDGV/T, HDGV, and LDF.
C
C LDGV/T and HDGV HC ef both have RVP exhaust and open loop technology
C cf. LDFG HC ef have no open loop technology credit, but gasoline RVP
C correction. LDFM HC ef have no open loop technology credit and are
C assumed to be independent of M85's RVP.
C
      OPENRE=1.0-OPENLP(IDX,IV)*OPENCR
      RVOPCF=FRGAS*RVPCF(IDX,IP,IV,1)
     *       +(FRETH*RVPCF(IDX,IP,IV,2)
     *       +FRMETH*RVPCF(IDX,IP,IV,1))*OPENRE
      IF(IV.EQ.9) RVOPCF=1.0
      IF(IV.EQ.10) RVOPCF=RVPCF(IDX,IP,1,1)
C
      EXHHC=EXHHC*RVOPCF
   25 EFEXH(IV)=EFEXH(IV)+EXHHC
      COMPEF=COMPEF+EXHHC
      IF(IV.GE.5.AND.IV.LE.7) GOTO 50
C
C Second, calculation of a HC combined evaporative (hot soak and diurnal)
C and crankcase emission factor by function CCEVRT.
C
      COMPCC=CCEVRT(MY,IDX,IV,RVPHS1,RVPHS2,CIGAS1,CIGAS2)
C
C If the user sets MCHOS2=3, the LDFG model year HC evaporative ef are the
C same as for LDGV.
C
      IF(IV.EQ.10.AND.MCHOS2.EQ.3.AND.MY.GE.1993)
     *         COMPCC=CCEVRT(MY,IDX,1,RVPHS1,RVPHS2,CIGAS1,CIGAS2)
C
      DO 30 IEVP=1,3
      EVPSUM(IEVP)=EVP(IEVP)*(1.0-FRETH)
   30 CONTINUE
      EVPSUM(4)=EVP(4)
C
C Third, calculation of running loss HC emissions for LDGV/T.
C
C Running losses for LDFG are calculated like for LDGV. For LDFM,
C RULOSS is called with RVPM85 as forth index.
C
      IF(IV.LE.4.OR.IV.EQ.10)
     *           RNGLOS=RULOSS(MY,IDX,IV,RVPHS1,RVPHS2)*(1.0-FRETH)
      IF(IV.EQ.9) RNGLOS=RULOSS(MY,IDX,IV,RVPM85,RVPHS2)
C
C If the user sets MCHOS2=3, the LDFG model year running loss ef are the
C same as for LDGV.
C
      IF(IV.EQ.10.AND.MCHOS2.EQ.3.AND.MY.GE.1993)
     *           RNGLOS=RULOSS(MY,IDX,1,RVPHS1,RVPHS2)*(1.0-FRETH)
```

```
C
      IF(FRETH.EQ.0.0) GOTO 40
      COMPCC=(1.0-FRETH)*COMPCC
     *        +FRETH*CCEVRT(MY,IDX,IV,RVPET1,RVPET2,CIETH1,CIETH2)
      DO 35 IEVP=1,3
      EVPSUM(IEVP)=EVPSUM(IEVP)+EVP(IEVP)*FRETH
   35 CONTINUE
      IF(IV.LE.4) RNGLOS=RNGLOS+RULOSS(MY,IDX,IV,RVPET1,RVPET2)*FRETH
C
C Weight by travel or registration fraction and summate.
C
   40 COMPCC=COMPCC*TF(IDX,IV)
      EFEVAP(IV)=EFEVAP(IV)+COMPCC
      COMPEF=COMPEF+COMPCC
      RNGLOS=RNGLOS*TF(IDX,IV)
      EFRUNL(IV)=EFRUNL(IV)+RNGLOS
      COMPEF=COMPEF+RNGLOS
      DO 45 IEVP=1,4
      EVPSUM(IEVP)=EVPSUM(IEVP)*JANMYR(JDX,IV)
      GREVP(IEVP,IV)=GREVP(IEVP,IV)+EVPSUM(IEVP)
   45 CONTINUE
C
C Forth, calculation of refueling losses for gasoline vehicles and LDF.
C
      IF(IV.EQ.5.OR.IV.EQ.6.OR.IV.EQ.7.OR.IV.EQ.8.OR.RLFLAG.EQ.5)
     *     GOTO 50
      GASCAP=RLRATE(IDX,IV)*TF(IDX,IV)
      EFLOSS(IV)=EFLOSS(IV)+GASCAP
C
C COMPEF adds up all HC emissions for one model year index (IDX).
C
      COMPEF=COMPEF+GASCAP
C
   50 EFFTP(IP,IV)=EFFTP(IP,IV)+COMPEF
C
C End loop through years
C
   55 CONTINUE
      IF(IV.EQ.4.OR.IV.EQ.7.OR.IV.EQ.8) GOTO 60
      IF(EFFTP(IP,IV).GT.0.0.AND.GSFRAC(IGS,IV,IREJN).EQ.0.0)
     *   CALL QUITER(0.,IV,67,INERR)
   60 IF(EFFTP(IP,IV).LE.0.0) CALL QUITER(0.,IV,68,INERR)
C
C Weighting by VMTMIX and REGMIX.
C
      VFTP(IP)=VFTP(IP)+EFFTP(IP,IV)*VMTMIX(IV)
      VEXH=VEXH+EFEXH(IV)*VMTMIX(IV)
      VEVAP=VEVAP+EFEVAP(IV)*VMTMIX(IV)
      VLOSS=VLOSS+EFLOSS(IV)*VMTMIX(IV)
      VRUNLS=VRUNLS+EFRUNL(IV)*VMTMIX(IV)
      DO 65 IEVP=1,3
      VGREVP(IEVP)=VGREVP(IEVP)+GREVP(IEVP,IV)*REGMIX(IV)
```

```
   65 CONTINUE
      VGREVP(4)=VGREVP(4)+GREVP(4,IV)*VMTMIX(IV)
C
C End loop through vehicle classes.
C
   70 CONTINUE
      IF(EFFTP(IP,2).GT.0.0.AND.EFFTP(IP,3).GT.0.0) EFFTP(IP,11)=
     *   (EFFTP(IP,2)*VMTMIX(2)+EFFTP(IP,3)*VMTMIX(3))/VMLDGT
      IF(EFEXH(2).GT.0.0.AND.EFEXH(3).GT.0.0)
     *   EFEXH(11)=(EFEXH(2)*VMTMIX(2)+EFEXH(3)*VMTMIX(3))/VMLDGT
      IF(EFEVAP(2).GT.0.0.AND.EFEVAP(3).GT.0.0)
     *   EFEVAP(11)=(EFEVAP(2)*VMTMIX(2)+EFEVAP(3)*VMTMIX(3))/VMLDGT
      IF(EFLOSS(2).GT.0.0.AND.EFLOSS(3).GT.0.0)
     *   EFLOSS(11)=(EFLOSS(2)*VMTMIX(2)+EFLOSS(3)*VMTMIX(3))/VMLDGT
      IF(EFRUNL(2).GT.0.0.AND.EFRUNL(3).GT.0.0)
     *   EFRUNL(11)=(EFRUNL(2)*VMTMIX(2)+EFRUNL(3)*VMTMIX(3))/VMLDGT
      DO 75 IEVP=1,3
      IF(GREVP(IEVP,2).GT.0.0.AND.GREVP(IEVP,3).GT.0.0)
     *   GREVP(IEVP,11)=(GREVP(IEVP,2)*REGMIX(2)
     *                 +GREVP(IEVP,3)*REGMIX(3))
     *                 /(REGMIX(2)+REGMIX(3))
   75 CONTINUE
      IF(GREVP(4,2).GT.0.0.AND.GREVP(4,3).GT.0.0)
     *   GREVP(4,11)=(GREVP(4,2)*VMTMIX(2)
     *              +GREVP(4,3)*VMTMIX(3))
     *              /VMLDGT
      RETURN
      END
```

APPENDIX E: SUBROUTINE EVMET

```
      SUBROUTINE EVMET(MY,IDX,IV,HS,DU)
C
C Subroutine EVMET calculates the hot soak (g) and diurnal (g) emissions for
C LDF.
C
      COMMON /FFVEV/ EVLDF(4),EXCESS(2),DEFMAL(2),EXH(2),DMH(2),
     *                 EXD(2),DMD(2)
      COMMON /TEMPS/  AMBT,TEMMIN,TEMMAX,TEMEXH(3),TEMEVP(6),TEMAST(3)
      COMMON /CITUSE/ RVUSE1,RVUSE2,CIUSE1,CIUSE2
      COMMON /CITCIN/ UDI(5),IUDI,CIGAS1,CIGAS2,CIETH1,CIETH2,ICERSW
      COMMON /TAMOUT/ TAMBAG(3,3,20,4),THS(2,20,6),TDU(20,4),TCC(20,4)
      COMMON /FFVCOM/ MAXMSF,FFVFRA(21),MYMSF(21),METFRA,RVPM85,INRVPM,
     *                 RVPMLS,MCHOS1,MCHOS2
      HS=0.0
      DU=0.0
      IF(TEMMAX   .LE.40.0 .OR.
     *   AMBT     .LE.40.0.AND.TEMFLG.EQ.2 .OR.
     *   TEMEVP(1).LE.40.0 .OR.
     *   TEMEVP(2).LE.40.0 .OR.
     *   TEMMIN   .LE.25.0) RETURN
      IF(MY.LT.1993) GOTO 90
      CALL EVRVPC
C
C Hot soak and diurnal calculation from FTP levels, RVP excess effect,
C malmaintenance and defect effects, and optional tampering effect.
C
      IF(IV.EQ.9) THEN
        HS=EVLDF(1)*EVTCOR(1,IV)
        DU=EVLDF(2)*EVTCOR(2,IV)
        HS=HS+EXH(1)*HS+DMH(1)*HS
        DU=DU+EXD(1)*DU+DMD(1)*DU
      ELSE IF(IV.EQ.10) THEN
        HS=EVLDF(3)*EVTCOR(1,IV)
        DU=EVLDF(4)*EVTCOR(2,IV)
        HS=HS+EXH(2)*HS+DMH(2)*HS
        DU=DU+EXD(2)*DU+DMD(2)*DU
      END IF
C
C If the user wants tampering to be included for either one or both of the
C LDF vehicle groups, the tampering offset for 1993+ LDGV with port fuel
C injection (PBI) applies. The tampering offset is additive and
C yields the same portion of the untampered ef as for 1993+ PBI LDGV.
C
      IF((IV.EQ.9.AND.MCHOS1.EQ.2).OR.(IV.EQ.10.AND.MCHOS2.EQ.2)) THEN
        CALL EVMAIN(MY,1,1,1,7,RVUSE1,HSCINJ)
        CALL EVMAIN(MY,1,2,1,7,RVUSE1,HSUINJ)
        HSTAM=((HSUINJ-HSCINJ)/HSCINJ)*THS(2,IDX,1)
        HS=HS+HSTAM
C
```

```
      RIVAL=UDI(2)/UDI(1)
      CALL EVMAIN(MY,2,1,1,7,RIVAL,DUCINJ)
      CALL EVMAIN(MY,2,2,1,7,   0.,DUUINJ)
      IF(DUUINJ.LT.DUCINJ) DUUINJ=DUCINJ
      DUTAM=((DUUINJ-DUCINJ)/DUUINJ)*TDU(IDX,1)
      DU=DU+DUTAM
     END IF
C
  90 RETURN
     END
```

APPENDIX F: SUBROUTINE EVRVPC

```
      SUBROUTINE EVRVPC
C
C Calculates the excess RVP effect and the malmaintenance and defect
C effect for LDF hot soak and diurnal emissions.
C
      COMMON /CITCIN/ UDI(5),IUDI,CIGAS1,CIGAS2,CIETH1,CIETH2,ICERSW
      COMMON /CITRV1/ RVPBAS,RVPIUS,RVPAST,RVPICY,RVPETH,IUSESY,RATUNC
      COMMON /CITUSE/ RVUSE1,RVUSE2,CIUSE1,CIUSE2
      COMMON /EVADU1/ DUEQ(3,2,10),EFDU(4,2),HDDU(2),CLDU(5,2),TPDU(8,2)
      COMMON /EVADU2/ HIDU(2),DULIM(3,2),R2DU(2,2),TPDUAF(7,4,2),IDUAF
      COMMON /EVAHS1/ HSEQ(3,2,12),EFHS(4,2),HDHS(2),CLHS(5,2)
      COMMON /FFVCOM/ MAXMSF,FFVFRA(21),MYMSF(21),METFRA,RVPM85,INRVPM,
     *                RVPMLS,MCHOS1,MCHOS2
      COMMON /FFVEV/ EVLDF(4),EXCESS(2),DEFMAL(2),EXH(2),DMH(2),
     *                EXD(2),DMD(2)
      RVPUSE=RVUSE1
      IF(RVPUSE.LT.8.0) RVPUSE=8.0
C
C Hotsoak
C
      DO 10 IEV=1,2
      EXCESS(IEV)=0.0
      DEFMAL(IEV)=0.0

      IF(IEV.EQ.1) RVPEV1=RVPM85
      IF(IEV.EQ.1) RVPEV2=RVPM85
      IF(IEV.EQ.2) RVPEV1=RVPICY
      IF(IEV.EQ.2) RVPEV2=RVPUSE

      EXCESS(IEV)=HSEQ(3,1,1)+HSEQ(3,1,2)*RVPEV1
     *                           +HSEQ(3,1,3)*RVPEV1**2

      DEFMAL(IEV)=HSEQ(3,1,4)+HSEQ(3,1,5)*RVPEV2
     *                       +HSEQ(3,1,6)*RVPEV2**2
C
C Normalize hot soak RVP excess and malmaintenance & defect effects.
C
      EXH(IEV)=EXCESS(IEV)/HSEQ(3,1,7)
      DMH(IEV)=DEFMAL(IEV)/HSEQ(3,1,7)
   10 CONTINUE
C
C Diurnal
C
      DO 20 IEV=1,2
      EXCESS(IEV)=0.0
      DEFMAL(IEV)=0.0
      IF(IEV.EQ.1) RVPEV1=UDI(2)/UDI(1)
      IF(IEV.EQ.1) RVPEV2=RVPM85
      IF(IEV.EQ.2) RVPEV1=UDI(2)/UDI(1)
```

```
      IF(IEV.EQ.2) RVPEV2=RVPUSE
      IF(RVPEV1.LE.DULIM(3,1))
     *     EXCESS(IEV)=DUEQ(3,1,1)+DUEQ(3,1,2)*RVPEV1
     *                        +DUEQ(3,1,3)*RVPEV1**2
      IF(RVPEV1.GT.DULIM(3,1))
     *     EXCESS(IEV)=DUEQ(3,1,9)+DUEQ(3,1,10)*RVPEV1

      DEFMAL(IEV)=DUEQ(3,1,4)+DUEQ(3,1,5)*CIUSE1
     *                   +DUEQ(3,1,6)*CIUSE1**2
      EXD(IEV)=EXCESS(IEV)/DUEQ(3,1,7)
      DMD(IEV)=DEFMAL(IEV)/DUEQ(3,1,7)
   20 CONTINUE
      RETURN
      END
```

APPENDIX G: SUBROUTINE BEF

```
   FUNCTION BEF(MY,IDX,ICY,IP,IV,VMTAGE,IBEFSW)
C
C Returns the basic emission factor for each model year/vehicle class
C group, adjusted for operating mode, CO temperature offset, methane
C offset, temperature, I/M and tampering offsets.
C
      COMMON /BASEQ1/ ERBZML(20,3,10,2),ERBDR(20,3,10,2),ERB50K(14,2,2)
      COMMON /BASEQ5/ ERUZML(12,3,10,2),ERUDR(12,3,10,2),ERU50K(14,2,2)
      COMMON /BASEQ6/ MYGERU(12,2,3,8,2),MAXERU,NUMERU(3,8,2),KEYER,IGER
      COMMON /OFFSET/ OFFCO(20,3),OFFMTH(20,10)
      COMMON /OMTCOM/ OMTCF(20,3,8),OMTTAM(20,3,4),FOMTAM(20,3)
      COMMON /REGION/ FEET(2),IREJN,ALT,INITPR
      COMMON /TAMEQ1/ TAMZML(9,4,2,2),TAMDR(9,4,3,2),MYGTAM(4),IGT5,F50K
      COMMON /FLAGS4/ PRTFLG,IDLFLG,NMHFLG,HCFLAG,METFLG
      COMMON /FFVCOM/ MAXMSF,FFVFRA(21),MYMSF(21),METFRA,RVPM85,INRVPM,
     *                RVPMLS,MCHOS1,MCHOS2
      COMMON /IOUCOM/ IOUIHD,IOUGEN,IOUREP,IOUERR,IOUASK
      ABOV50=VMTAGE-F50K
      KINK50=1
      IF(MY.GE.1981.AND.IP.LE.2.AND.(IV.EQ.1.OR.IV.EQ.9.OR.IV.EQ.10).
     *     AND.ABOV50.GT.0.0) KINK50=2
C
C Look up base emission rates and deterioration rates using pointer
C IERPTR.
C
      CALL IERPTR(MY,IP,IV)
      IF(KEYER.EQ.2) GOTO 10
      ZPOINT=ERBZML(IGER,IP,IV,IREJN)
      SLOPE1=ERBDR( IGER,IP,IV,IREJN)
      IF(KINK50.EQ.1) GOTO 20
C
C Pointer IGER50 for deterioration rates of 50k+ model year groups.
C
      IF(MY.LE.1992) IGER50=MY-1981+1
      IF(MY.GT.1992) IGER50=12
C
C Call of second slope for LDF.
C
      IF(MY.GT.1992.AND.IV.EQ.9) IGER50=13
      IF(MY.GT.1992.AND.IV.EQ.10) IGER50=14
C
      SLOPE2=ERB50K(IGER50,IP,IREJN)
      GOTO 20
   10 ZPOINT=ERUZML(IGER,IP,IV,IREJN)
      SLOPE1=ERUDR( IGER,IP,IV,IREJN)
      IF(KINK50.EQ.2) SLOPE2=ERU50K(IGER,IP,IREJN)
C
C Calculation of uncorrected emission rates, only from zml and dr.
C
```

```
   20 IF(KINK50.EQ.1) BEF=ZPOINT+SLOPE1*VMTAGE
      IF(KINK50.EQ.2) BEF=ZPOINT+SLOPE1*F50K+SLOPE2*ABOV50
      IF(IBEFSW.EQ.1) GOTO 99
C
C write out BEF.
C
C      IF((IV.EQ.9.OR.IV.EQ.10).AND.IDX.EQ.1) THEN
C      WRITE(10,100) IV,IP
C  100 FORMAT('0','Uncorrected bef for vehicle class ',I2,' and',
C     *       ' pollutant ',I1,' are:')
C      END IF
C      IF((IV.EQ.9.OR.IV.EQ.10).AND.IDX.EQ.1) THEN
C      WRITE(10,110) BEF
C  110 FORMAT(' ',1X,F6.3)
C      END IF
C      IF(IV.EQ.9.OR.IV.EQ.10) THEN
C      WRITE(10,120) BEF
C  120 FORMAT(' ',1X,F6.3)
C      END IF
C
C Applying of correction factors.
C
C The exhaust ef correction factors for LDF are calculated seperately from
C those for the other vehicle classes.
C
      IF(IV.EQ.9.OR.IV.EQ.10) GOTO 30
C
C Start correction factor calculation for vehicle classes 1 through 8.
C
C CO offset for LDGV/T.
C
      IF(IV.LE.3.AND.IP.EQ.2)
     *    BEF=(BEF*OMTCF(IDX,IP,IV)*PCLEFT(MY,ICY,IP,IV))+OFFCO(IDX,IV)
C
C Methane offset.
C
      IF(IP.EQ.1)
     *    BEF=(BEF*OMTCF(IDX,IP,IV)-OFFMTH(IDX,IV))*PCLEFT(MY,ICY,IP,IV)
C
C Offset for temperature and inspection/maintenance.
C
      IF(IP.EQ.3.OR.(IV.GT.3.AND.IV.LE.8.AND.IP.EQ.2))
     *    BEF=BEF*OMTCF(IDX,IP,IV)*PCLEFT(MY,ICY,IP,IV)
C
C Saving of LDGV proportional tampering effect for application to LDF.
C
      IF(IV.EQ.1) THEN
        FOMTAM(IDX,IP)=OMTTAM(IDX,IP,IV)/BEF
      END IF
C
C Addition of tampering bag emissions, corrected for operation mode and
C temperature.
```

```
C
      IF(IV.LE.4) BEF=BEF+OMTTAM(IDX,IP,IV)
      GOTO 99
C
C Start correction factor calculation for LDF.
C
C Function EXTCOR generates the multiplicative temperature offset, function
C CH4COR generates the multiplicative methane offset, if non-methane HC are
C requested.
C
   30 BEF=BEF*EXTCOR(IP,IV)
      IF(NMHFLG.EQ.2.AND.IP.EQ.1) BEF=BEF*CH4COR(IP,IV)
C
C If the user wants tampering to be included for either one or both of the
C LDF vehicle groups, an additive tampering offset applies. The offset
C yields the same portion of the untampered rate as for LDGV of the same
C model year and is corrected for operation mode, temperature and ATP, if
C one applies.
C
      IF(IV.EQ.9.AND.MCHOS1.EQ.2) BEF=BEF+FOMTAM(IDX,IP)*BEF
C
      IF(IV.EQ.10.AND.MCHOS2.EQ.2) BEF=BEF+FOMTAM(IDX,IP)*BEF
C
   99 RETURN
      END
```

APPENDIX H: SUBROUTINE EXTCOR

```
     FUNCTION EXTCOR(IP,IV)
C
C Calculates the multiplicative temperature offset for LDF and all three
C exhaust pollutants by 2-point interpolation.
C
      COMMON/FFVCOR/ CORTEM(3),C4COR(3,2),TMCOR(3,3,2),ETCOR(3,2,2)
      COMMON /TEMPS/ AMBT,TEMMIN,TEMMAX,TEMEXH(3),TEMEVP(6),TEMAST(3)
C
C  DATA: Multiplicative correction factors for LDFM and LDFG HC, CO, and
C        NOx exhaust emissions to correct for non-FTP temperatures, calculated
C        from Gabele (1990).
C
      DATA CORTEM/40.0,75.0,90.0/
      DATA TMCOR/
C LDFM  40F  75F  90F
     H  2.91,1.00,1.13,
     C  3.38,1.00,1.08,
     N  0.91,1.00,1.18,
C LDFG
     H  4.33,1.00,1.19,
     C  3.27,1.00,0.92,
     N  1.08,1.00,1.19/
C
C If the exhaust temperature is below 40F, the cf for 40F applies,
C accordingly for exhaust temperatures over 90F.
C
      IF(TEMEXH(IP).LE.CORTEM(1)) THEN
        EXTCOR=TMCOR(1,IP,IV-8)
        GOTO 30
      ELSE IF(TEMEXH(IP).GE.CORTEM(3)) THEN
        EXTCOR=TMCOR(3,IP,IV-8)
        GOTO 30
      ELSE
C
C Find bracketing temperature and associated factors.
C
        DO 10 ITE=1,2
        IF(TEMEXH(IP).LE.CORTEM(ITE)) GOTO 20
   10   CONTINUE
        ITE=3
   20   TMP1=CORTEM(1)
        IF(ITE.GT.1) TMP1=CORTEM(ITE-1)
        TMP2=CORTEM(ITE)
        COR1=0.0
        IF(ITE.GT.1) COR1=TMCOR(ITE-1,IP,IV-8)
        COR2=TMCOR(ITE,IP,IV-8)
C
C Interpolate.
C
```

```
      EXTCOR=COR1*((TMP2-TEMEXH(IP))/(TMP2-TMP1))+
     *          COR2*((TEMEXH(IP)-TMP1)/(TMP2-TMP1))
      END IF
   30 RETURN
      END
```