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MOBILE6
A Revised Model for Estimation of Highway Vehicle Emissions

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Abstract

The Environmental Protection Agency (EPA) highway vehicle emission factor model provides average in-use fleet emission factors for three criteria pollutants [volatile organic compounds (VOC), a precursor of ground-level ozone; carbon monoxide (CO); and oxides of nitrogen (NOx)], for gas and diesel cars and light- and heavy-duty trucks, and motorcycles, for calendar years between 1970 and 2050, under various conditions affecting in-use emission levels (e.g., ambient temperatures, average traffic speeds) as specified by the modeler. It is used by EPA in evaluating highway mobile source control strategies, by States (except California) and local and regional planning agencies in developing emission inventories and control strategies for State Implementation Plans (SIPs) under the Clean Air Act, and in the development of environmental impact statements.

EPA is now in the process of revising the MOBILE model. MOBILE6, currently scheduled for release in December 1999, will differ significantly in both structure and data requirements from current versions of the model (MOBILE5a and 5b). MOBILE6 will incorporate updated basic emission rates, off-cycle ("real world") driving patterns and emissions, separation of start and running emissions, improved correction factors, and updated fleet information. It will also include impacts of recently promulgated regulations not included in MOBILE5a, and will provide improved input and output features.

Introduction

Under requirements of the Clean Air Act (CAA) amendments of 1990, Section 130[1], EPA (as represented by the Administrator) is required to "...review and, if necessary, revise, the methods ("emission factors") use for purposes of this Act to estimate the quantity of emissions of carbon monoxide, volatile organic compounds, and oxides of nitrogen from sources of such air pollutants (including area sources and mobile sources)." For the case of highway vehicles, these emission factors are calculated using a computer model; the most recent major update to this model, MOBILE5a, was released for use in March 1993. Since that time, two additional updates to this model have been released, MOBILE5a_H and 5b; the latter were released in August 1997. EPA's Office of Mobile Sources (OMS) is now working on a major update to this model. The new version, MOBILE6, is currently planned for final release in December 1999.

In addition to the need for updating the model's underlying emission test data to reflect testing and analyses that have been performed since MOBILE5b, OMS is aware that the output of the existing model is not always well suited to the needs of the large and diverse audience for the model. In particular, there is a clear need for better integration of emission factor and air quality modeling with transportation planning and analyses. One example of this is the need for emission factors representing time periods less than a full day (such as the need for hourly emission estimates for use in Urban Airshed Modeling), and for emission factors that better represent variations in traffic flow patterns (and hence emission rates) across various roadway (or facility) types. As discussed below, OMS is making significant changes to the model structure and output to address such concerns.

Finally, OMS is developing this revision to the MOBILE model using a much more intensive process of obtaining outside review during development. Among the steps being taken is the extensive provision of opportunities for stakeholder review of various components of the model and underlying analyses at an earlier stage of the process, and obtaining formal peer review of such components and analyses where appropriate. The reader is referred to the OMS Home Page on the World Wide Web (http://www.epa.gov/oms) for additional information on the development of MOBILE6, including information on the review processes being utilized to ensure that all components of the pending model revision are widely disseminated.

The following sections describe the updates and revisions being made to the MOBILE model, the types and sources of data being used in these updates (where applicable), changes to the input data requirements and output report format and content, and the stakeholder and peer review processes being used in the development of MOBILE6. There is still much work to be done in most areas of the model; thus, it is not possible at this time to provide "bottom line" answers as to exactly what impacts these changes will have on highway vehicle emission factor estimates and emission inventories developed from those factors. Where possible, indications are provided as to the direction and approximate magnitude of each revision. Only after more work has been completed and reviewed will it be possible to provide an estimate of the impact on emission estimates of all of the proposed changes in the aggregate.

As part of the development of MOBILE6, OMS has established a section within its web site (http://www.epa.oms/oms) that includes drafts of analyses and papers that have been prepared. These reports are posted for outside (stakeholder) review and comment. That section of the web site is accessed by selecting "MOBILE6" from the choices available at the OMS home page (web address shown above). Papers cited having report numbers of the form M6.xxx.yyy, where "xxx" represents a topical area (e.g., "EXH" represents papers dealing with analysis of exhaust emissions, "EVP" represents papers dealing with analysis of evaporative emissions, and so forth) and "yyy" indicates a number within that series (001, 002, etc.), can be accessed at the OMS web site. OMS also provides a list server (an electronic e-mail mailing list) to announce the posting of new reports and other mobile source modeling developments. The OMS web site contains information on how to subscribe to the EPAMOBILENEWS list server.

Discussion

Emission data updates

- Reevaluation of in-use deterioration (for light-duty vehicles and light-duty trucks) and update of basic emission rate equations (for light-duty vehicles, light-duty trucks, and heavy-duty vehicles)

EPA is nearing completion of a major reassessment of the magnitude of in-use deterioration for light-duty vehicles (LDVs) and light-duty trucks (LDTs). "Deterioration" here is defined as the rate of increase in emission rates as a combination of emission from both properly maintained, non-tampered vehicles and high emitting vehicles as a function of accumulated vehicle mileage. Basic emission rate equations in the MOBILE model express emissions for such vehicles, specific to unique combinations of vehicle type/model year/pollutant, as a "zero-mile" level (expressed in grams per mile, or g/mi) and one or more rates of deterioration [expressed in g/mi per 10,000 miles accumulated mileage, or (g/mi)/10K mi]. The deterioration rates used in MOBILE5 were substantially higher than those used in the preceding MOBILE4.1 model, as evidenced by the test data collected and analyzed in the late 1980s and early 1990s. However, since the release of MOBILE4.1, evidence that these deterioration rates were not applicable to newer (post-1990 model year) LDVs and LDTs began to appear from a variety of sources.

This reevaluation of in-use deterioration rates has been performed under the advice and guidance of the Mobile Source Technical Advisory Subcommittee of the Clean Air Act Advisory Committee, established under the Federal Advisory Committee Act (FACA). The results of this work have not yet been approved for final release and use in the model; however, the general trend is clear that in-use deterioration from newer vehicles (approximately model year 1990 and newer) will be less than had been modeled in MOBILE5. This change is likely to result in lower emission factors for all pollutants from LDVs and LDTs, for all calendar years from 1991 forward. This change is also likely to have the effect of reducing the benefits available from the imposition of in-use inspection and maintenance (I/M) programs.

However, this change is not occurring in isolation; a large number of other revisions and updates, as briefly described in the following sections, are also being implemented for MOBILE6. At this time, it is impossible to quantify the overall impact of all of the changes being made on the emission factors calculated by the model.

- Off-cycle effects

The Federal Test Procedure (FTP) has been used as the basic test cycle for emissions measurements (including certification of new vehicles to applicable exhaust standards and characterization of emissions from in-use vehicles) since the early 1970s. Among the most important shortcomings of the FTP are the limits on speed and acceleration rates. At the time that the FTP was developed, limitations on dynamometers prevented the inclusion of vehicle speeds higher than about 60 mph, or of acceleration rates greater than 3.4 mph/sec. Particularly since the repeal of the national 55 mph speed limit, a significant fraction of total vehicle miles traveled (VMT) are accumulated at speeds greater than 55 mph, and acceleration rates well over 3.4 mph/s (up to at least 8 mph/s) are not uncommon. Both of these have a significant impact on emissions. Driving behavior not fully captured by the FTP is referred to as off-cycle (or non-FTP) driving.

EPA has developed a new test procedure (the Supplemental FTP, or SFTP) in response to requirements of the 1990 Clean Air Act Amendments, which includes vehicle operation at higher speeds and higher acceleration rates. Future model years will be required to meet emission standards using the SFTP and will be required to mitigate the emission impacts of off-cycle driving behavior.

Related to off-cycle driving is the impact of vehicle air conditioning (A/C) on emission rates. Historically, EPA has simulated the impacts of A/C during emission testing by increasing the load on the vehicle. More recently, testing has shown that these simulations do not adequately capture the true impacts of A/C use on emissions. When vehicles are tested on a chassis dynamometer with the A/C actually "on" in an environmentally controlled testing cell, the emissions impacts observed have been considerably greater than those seen by simulating the impact of A/C on emissions by the added load.

MOBILE6 is being developed to account for the impacts of driving behaviors not represented by the FTP (off-cycle), the impacts of newer vehicles being certified using the SFTP, and the impacts of A/C on emissions. While much work remains to be done, the broad outlines of the impacts of these changes can be characterized. Special emission testing was done using a variety of new driving cycles that include off-cycle behavior. Inclusion of non-FTP ("off-cycle" or "real-world") driving patterns will result in a significant increase, relative to MOBILE5 estimates, for all pollutants. This effect will be most pronounced for evaluation years in the 1990s. As new vehicles are certified using the SFTP, beginning in the 2001 model year, this impact will be greatly reduced; however, only after 25 model years (the window of model years in operation that is used in the MOBILE model's emission factor calculations) have passed after

implementation of certification using the SFTP will the emission factor increases associated with modeling such off-cycle driving be completely eliminated.

With respect to the modeling of A/C impacts, the reader is referred to the reports "Air Conditioning Activity Effects in MOBILE6" (M6.ACE.001)[2] and "Air Conditioning Correction Factors in MOBILE6 (M6.ACE.002)[3]. EPA intends that a number of parameters affecting the magnitude of the A/C effect on emission factors will be under the control of the modeler through specifications in the input data file. The testing used to develop these emission effects included extreme ambient conditions (i.e., very high temperatures, humidity levels, full solar load) intended to capture the impact of all vehicles equipped with A/C operating full time. User control of these parameters will allow the impacts on emissions of A/C use to be "scaled down" to lesser levels, representative of less extreme ambient conditions. Since practical constraints prohibited the testing of vehicles over a range of temperatures, humidity levels, and solar loads, both with and without the A/C in operation, an approach to modeling the effects of A/C at intermediate conditions is developed and presented in the above paper.

- Update fuel effects on emissions

MOBILE5 includes the impacts on in-use emissions of several properties of gasoline: volatility (as measured by Reid vapor pressure), oxygenate content (for both alcohol/gasoline and ether/gasoline blends), and sulfur level. Such modeling is required in order to account for the fact that new vehicle certification, and most in-use emission factor testing (excluding that aimed at characterization of fuel property impacts on emissions), is performed using specially formulated fuel that meets certain requirements. Over the past few model updates, EPA has incorporated volatility (RVP) effects on both exhaust and evaporative emissions into the model and provided the model user with the ability to specify in-use RVP levels. MOBILE5 also provided for modeler control of fuel oxygen content and market share. In addition, EPA adjusted the basic emission rates for all gasoline-fueled vehicle types to account for other fuel properties (such as sulfur content) in the industry average fuel that differed from the EPA test fuel specifications. However, no user control of sulfur levels or other fuel parameters was included for MOBILE5 or earlier versions of the model.

The primary updates to the effect of fuels planned for MOBILE6 are in the areas of oxygenate and sulfur effects. (The only change in the volatility corrections is the separation of RVP effects for start and for running emissions, as noted in the section on that topic below.) For oxygenates, the user of the model specifies the market share (fraction of all gasoline consumed in the area being modeled) of alcohol blend fuels and of ether blend fuels, and the average oxygen content (in weight percent) of each of these oxygenated fuel types. This user control will be maintained in MOBILE6; however, on the basis of new test data, the impact of fuel oxygen content on carbon monoxide (CO) emissions is being reduced, relative to that seen in MOBILE5a. Additional information on the data used for this analysis and the resulting changes in the modeled impact of oxygenated fuels can be found at the MOBILE6 section of the OMS web site, in the paper "Fuel Oxygen Effects on Exhaust CO Emissions"(M6.FUL.002)[4].

Considerable interest in the impact of fuel sulfur levels on in-use emissions has developed in the last few years, as emission standards continue to be tightened and the wide variation in sulfur levels in different parts of the country are better known. MOBILE5 contains an average correction factor for sulfur content, increasing emission factors slightly to reflect the nationwide average sulfur content of 339 ppm relative to the test fuel maximum sulfur content of 50 ppm. In response to demand from States and other parties who need to have this impact better characterized, and to be in a position to evaluate the potential benefits of sulfur control regulations, OMS is planning to add the capability for the user to input average fuel sulfur content data for MOBILE6. This will enable the modeler to specify an in-use sulfur level, within the limits of the model, and have the resulting impact reflected in the emission factors calculated by the model. These analyses have not yet completed internal review and are not yet available at the OMS web site. The range of sulfur levels that the user of MOBILE6 will be able to specify, while subject to change, is likely to be from 30 to 600 ppm.

- Roadway (facility) type and average speed correction factors

MOBILE5 and previous versions of the model have based emission factor estimates on a single value of "average" speed. The average speed of the FTP driving cycle (the LA4 at 19.6 mph), provided the basic emission rates for MOBILE5 and was considered to be "uncorrected" for speed. When the modeler indicated an average speed other than 19.6 mph, the base emission factors were corrected to that speed. The range of permissible average speeds in MOBILE5 is 2.5 to 65 mph. However, different roadways (facility types in transportation terminology) can have very different patterns, in terms of frequency and magnitude of accelerations (for example), while still maintaining the same average speed. Consider the case of "average speed" of 25 mph on a roadway with a posted limit of 30 mph, and on a freeway with a posted limit of 65 mph; in the first case, if traffic is averaging 25 mph, it is essentially free flowing (except for signals, stops, and the like), while in the second case, traffic is very congested, likely includes stop-and-go driving, and may include brief excursions to speeds nearing 65 mph.

While the available data do not permit OMS to resolve this issue for all speeds on all facility types, we are taking the first major steps toward incorporating facility types into the emission factors produced by the model. This will provide more realistic emissions estimates for two major facility types (arterials and freeways) on which much VMT is accumulated, and will provide a significant step toward better integration of emission factor and traffic/transportation models.

MOBILE6 as now planned will include an emission adjustment for "local roadways" and for freeway on/off ramps, and will enable the modeler to specify (within limits) the average speed to be assumed for arterials and freeways. Area-wide emission factors for each pollutant and vehicle type will be calculated as a weighted sum of the four facility-specific emission factors (local/collectors, arterials, freeways, and ramps), with the user able to control the weighting factors used or using a national average set of weighting factors included within the model. The emission factors for the various facility types, and (in the cases of arterials and

freeways) at various average speeds, are based on vehicle testing over a series of facility cycles intended to better represent driving patterns actually observed on each respective facility type. The development of the facility cycles is detailed in an EPA report "Development of Speed Correction Cycles"[5] prepared by Sierra Research under contract to OMS. This report (M6.SPD.001) can be found at the MOBILE6 section of the OMS web site.

- Diurnal evaporative emissions based on real-time diurnal testing

Diurnal evaporative emissions are those emissions of gasoline vapors that occur as a result of increasing ambient temperatures during times that a vehicle is not being operated. The increased temperatures lead to increased fuel tank temperatures, leading to vapor generation and increased fuel system pressure, and hence to vapor release. When the vehicle is running, any diurnal vapors are routed to the engine intake manifold and burned. The base diurnal emission factors calculated by earlier versions of the MOBILE model were determined using a test procedure that simulated the diurnal temperature rise from 60-84°F (16-29°C) over a period of one hour. Results from testing over other temperature ranges and using other fuel RVP levels were used to develop estimated diurnal emission factors for other temperature rises and fuel volatilities.

Along with the implementation of enhanced evaporative emission control regulations, EPA and others have tested vehicles over the "real-time diurnal" test, in which emissions are measured over a period of hours with the temperature of the vehicle and SHED (sealed housing for evaporative determination) being increased over real time (as contrasted to forcing the heat build to occur over one hour using a heat blanket on the vehicle fuel tank). The results of this testing, which also included hourly measurements of diurnal emissions, are being used to develop new and more realistic diurnal emission factors for use in MOBILE6. The hourly measurements during these real-time diurnal tests are also being used in the development of hour-by-hour emission factor outputs, which are described under "Structural Changes" later in this paper.

The use of the real-time diurnal test results is also providing a means for improving the estimates of multi-day diurnal emissions (that is, those diurnal emissions generated on the second or greater consecutive day that a vehicle is not driven, and therefore is not providing an opportunity for the carbon canister used to control such emissions to be purged). Some vehicles have been tested over "real time" diurnal cycles spanning three or more days, uninterrupted by driving (and without canister purging). MOBILE5, in general terms, assumed that a second consecutive no-drive day resulted in diurnal emissions approximately twice the level of a single day's diurnal, and that third (or greater) consecutive no-driving days resulted in diurnal emissions at uncontrolled levels (that is, these emissions were similar to those produced by vehicles completing lacking evaporative emission control systems). The actual measurements indicate that these effects are overstated. MOBILE6 will reflect the new evaporative emission estimates.

Considerable information on real-time diurnal testing and how the results are being used in the development of MOBILE6 is presented in the paper "Modeling Hourly Diurnal Emissions

and Interrupted Diurnal Emissions Based on Real-Time Diurnal Data" (M6.EVP.002)[6]. Additional analyses and papers on the topics of real-time diurnal emissions, multi-day diurnal emissions, and related topics are still under internal OMS review, and are scheduled to be completed and posted on in the MOBILE6 section of the OMS Web site early in 1999.

- Update hot soak evaporative emission factors for RVP < 9.0 psi

"Hot soak" emissions are those evaporative emissions generated at the end of a vehicle trip ("trip-end" emissions) due to increased temperatures in the fuel tank, fuel delivery and evaporative emission control lines, and engine compartment. These emissions are primarily a function of trip duration, but are also dependent on ambient temperature and fuel volatility (as measured by Reid vapor pressure (RVP)). MOBILE5 and previous versions have based the hot soak emission factors on testing over a range of temperatures and fuel RVP levels, but have not included test data from "low volatility" (i.e., < 9.0 psi RVP) gasolines. MOBILE6 will include revised estimates of hot soak emissions for cases where the in-use (user specified) fuel volatility is less than 9.0 psi RVP.

Considering the relatively large data sets used for estimation of hot soak emission rates in the 9.0-11.5 psi RVP range, particularly at 9.0 psi RVP (the volatility of vehicle certification test fuel), compared to the still relatively small quantity of data available for RVPs < 9.0 psi, the new emission estimates for RVP < 9.0 psi were matched to the current (MOBILE5) estimates at 9.0 psi for any given ambient temperature. This revision is not expected to make a large difference in hot soak emission estimates, but should result in more accurate emission factors for RVPs < 9.0 psi, which represents virtually the entire country during the ozone formation season. Details of the data used and analyses performed are presented in the report "Update of Hot Soak Emissions Analysis" (M6.EVP.004)[7], prepared for EPA under contract by ARCADIS Geraghty & Miller. This report will be made available for review in the MOBILE6 section of the OMS Web site.

- Update heavy-duty engine emission conversion factors

Heavy-duty engines (HDEs) are defined as engines used in completed vehicles, gas or diesel, that have a gross vehicle weight rating (GVWR) over 8,500 lbs. Emissions from such engines are regulated in terms of grams per brake horsepower-hour (g/bhp-hr). For use in emission factor calculations, such as are performed by the MOBILE model, and in the development of emission inventories based on such emission factors, the need is for emissions expressed in terms of grams per mile (g/mi). "Conversion factors," in units of bhp-hr/mi, are used to convert emissions from g/bhp-hr to g/mi for both gas and diesel HDEs in the MOBILE model.

Such conversion factors are a function of several variables, notably in-use fuel consumption rates (generally expressed as brake specific fuel consumption, or BSFC), fuel economy (miles per gallon), fuel density, and non-engine related fuel economy improvements

(e.g., low rolling resistance tires, reductions in aerodynamic drag). Over the years, as each of the variables affecting the conversion factors change, the conversion factors themselves change, generally in the direction of reducing the in-use g/mi emission factor associated with a given g/bhp-hr emission rate. MOBILE6 will include updated conversion factors for all gas and diesel HDE vehicles. Much of the new data used in this analysis came from the 1992 Truck Inventory and Use Survey (TIUS)[8], and is detailed in a pair of reports prepared by ARCADIS Geraghty & Miller under contract to EPA: "Update Heavy-Duty Engine Emission Conversion Factors for MOBILE6: Analysis of Fuel Economy, Non-Engine Fuel Economy Improvements, and Fuel Densities" (M6.HDE.002)[9] and "Update Heavy-Duty Engine Emission Conversion Factors for MOBILE6: Analysis of BSFCs and Calculation of Heavy-Duty Engine Emission Conversion Factors (M6.HDE.004)[10]. Both of these reports have been posted in the MOBILE6 section of the OMS Web site.

- Update fleet characterization data

The term "fleet characterization data" refers to data describing the overall population of registered vehicles in use and the rates at which they are used (registration distributions and annual mileage accumulation rates by age and vehicle type). Emission data is specific to various types and ages of vehicles, and the relative contribution of vehicles of differing ages is a function of how many miles such vehicles are operated. In the MOBILE model, the two main types of fleet characterization data are registration distributions by age and annual mileage accumulation rates by age, each of which is defined distinctly for each vehicle type included in the model. Registration distributions by age, for each vehicle type, are a set of fractions that sum to 1.0 and describe what fraction of all vehicles of type X are of age Y at a given point in time. The MOBILE model explicitly accounts for 25 model years for each vehicle type, with the small number of vehicles greater than 25 years of age included within "age 25." Annual mileage accumulation rates describe how many miles per year vehicles of type X and age Y are operated.

All of the registration distributions and annual mileage accumulation rates by age are being updated for MOBILE6. Details of this analysis and the sources of data used are provided in the report "Update of Fleet Characterization Data for Use in MOBILE6" (M6.FLT.002)[11], which was prepared by Arcadis Geraghty & Miller under contract to EPA and is posted in the MOBILE6 section of the OMS Web site.

- Other activity rates

While the primary activity rate used in the development of highway mobile source emission inventories is total vehicle miles traveled (VMT), which is multiplied by appropriate emission factors in g/mi to yield total emissions, there are a number of other activity rates used within the MOBILE model. Most of these are used to weight together emission rates corresponding to specific situations experienced by some fraction of all vehicles in order to obtain "overall average" emission rates. Examples of these types of activity factors include the distribution of soak times (engine off time) preceding starts, used to estimate average start

emissions (see following section) and average hot soak (trip end) emissions, and average trip durations (lengths, in terms of time rather than distance), which determine the rate of running loss emissions.

Many of these "internal" activity rates are being updated for MOBILE6 using recent instrumented vehicle data. For more information, the reader is referred to the following reports, all of which are available at the MOBILE6 section of the OMS Web site: "Soak Length Activity Factors for Start Emissions"[12], "Soak Length Activity Factors for Hot Soak Emissions"[13], and "Trip Length Activity Factors for Running Loss and Exhaust Running Emissions."[14]

Structural changes

A number of changes being made for MOBILE6 are not to the emission factors *per se*, but rather to the structure of the model in terms of how emission factors are calculated and expressed, what types of input are required of (or can optionally be provided by) the modeler, and how the output is presented. The most important of these are briefly described in this section.

- Separation of start and running emissions

The MOBILE model historically has provided a single emission factor in g/mi for any unique combination of vehicle type, pollutant, and scenario (defined by user-specified conditions, such as ambient temperature and fuel RVP, and requested year of evaluation). The effects of engine operating mode (cold start, hot start, hot stabilized operation) have been handled through the use of "operating mode fractions," which define the fraction of VMT assumed to be accumulated in each operating mode. Through manipulation of the operating mode fraction inputs, the modeler was able to obtain emission factors corresponding to any combination of cold start, hot start, and hot stabilized operation. The most widely used sets of fractions included some of each operating mode, in order to represent overall area-wide daily average emissions.

As the transportation and air quality sectors have been better integrated in recent years, there is a growing need for a more detailed breakout of daily emissions. To respond to this need, OMS is revising the model to produce separated "start" and "running" emission factors. "Running" emission factors will continue to be represented in terms of g/mi emission rates, and will be based only on hot stabilized engine operation (which in turn represents most VMT in most areas at most times). "Start" emissions will be presented in terms of emission increments; that is, the added emissions resulting from vehicle start-ups. This will facilitate the modeling needs of many users, especially those requiring spatial and temporal allocation of emissions. The user will have the ability to specify a distribution of engine off (soak) times, while the model will contain a default distribution representing national average conditions. Thus, the previous (and somewhat arbitrary) distinction between "cold starts" and "hot starts" will be replaced by a more realistic representation of the range of conditions (i.e., distribution of soak times) preceding engine starts, and these start emissions can then be allocated to specific locations within an area and specific times of day.

For more information on how OMS has analyzed start and running emissions and determined the distribution of soak times preceding vehicle starts, see the reports "Soak Length Activity Factors for Start Emissions"[12], "Determination of Start Emissions as a Function of Mileage and Soak Time for 1981-1993 Model Year Light-Duty Vehicles"[15], and "Determination of Hot Running Emissions from FTP Bag Emissions"[16], all of which are available at the MOBILE6 section of the OMS Web site.

- Expansion of vehicle classes

The MOBILE model has provided emission factors for eight vehicle types in past versions: light-duty gasoline vehicles (LDGV, passenger cars with gasoline engines up to 6000 lb GVW), light-duty gas trucks (LDGT) I and LDGT II (gasoline-fueled light trucks up to 6000 lb GVW, and 6001-8500 lb GVW, respectively), heavy-duty gasoline vehicles (HDGV, trucks 8501 lb GVW and up equipped with heavy-duty gasoline engines), light-duty diesel vehicles (LDDV, passenger cars with diesel engines up to 6000 lb GVW), light-duty diesel trucks (LDDT, up to 8500 lb GVW), heavy-duty diesel vehicles (HDDV, trucks 8501 lb GVW and up equipped with heavy-duty diesel engines), and motorcycles (MC, includes only motorcycles certified for on-highway use and assumed to be all gasoline-fueled). The LDGT I and LDGT II breakdown was included because there are different emission standards applicable to these two subgroups; there is no similar break for diesel LDTs as the same emission factors apply to all diesel LDTs up to 8500 lb GVW.

MOBILE6 will provide distinct emission factor calculations for a wider range of vehicle categories, in part due to evolving regulations (i.e., the breakdown of LDGTs into four rather than two subgroups), and in part due to the needs of the modeling community (i.e., breakdown of HDGVs and HDDVs by GVW categories). The modeler will still be provided with the familiar eight vehicle types as listed above, but will be able to obtain a breakdown of emission factors by finer distinctions for vehicle categories. The current EPA proposal is: LDGVs, LDDVs, LDDTs, and MCs remain defined as currently, with no further breakdown are available; LDGTs can be divided into four categories, up from the current two, in accordance with emission standards issued under the 1990 Clean Air Act amendments; and HDGVs and HDDVs can be divided into a number of smaller groups. For HDGVs, separate emission factors will be available for Class IIb (8501-10,000 lb GVW), Class III (10,001-14,000 lb GVW), Class IV (14,001-16,000 lb GVW), Class V (16,001-19,500 lb GVW), Class VI (19,501-26,000 lb GVW), Class VII (26,001-33,000 lb GVW), and Class VIII (33,001 lb GVW and up), as well as for gasoline-fueled buses (including all types of buses). For HDDVs, a similar breakdown will be available (Classes IIb through VII), with Class VIII further divided into Class VIIIa (33,001-60,000 lb GVW) and VIIIb (60,001 lb GVW and up), and buses further divided into diesel school buses and diesel transit/commercial buses).

EPA is still working on these new vehicle categories and subcategories and how emission factors for each will be calculated. As additional information becomes available it will be posted in the MOBILE6 section of the OMS Web page.

- Inclusion of CNG vehicles

There is an increasing demand for emission factor calculations for alternatively fueled vehicles. Of the various alternative fuels being developed, only compressed natural gas (CNG) vehicles are currently in use in sufficient numbers with sufficient data to allow EPA to estimate emission factors for such vehicles. At the option of the modeler, a fraction of each of the vehicle types outlined above can be specified as being CNG vehicles in MOBILE6, and the resulting emission factors by vehicle category will account for the different emissions from CNG vehicles (relative to their gasoline-fueled or diesel counterparts), weighted by their fractions of each category. At this time there are no data to determine if CNG vehicles are operated differently than the gas or diesel vehicles that they replace, thus the activity levels, annual mileage accumulation rates by age, and other non-emission parameters of such vehicles will be assumed the same as the gas (or diesel) counterparts in MOBILE6.

- Hourly calculation/output of emission factors

MOBILE5 and earlier versions of the model have provided emission factor estimates that are based on an entire day (daily average emission factors). Among the assumptions made that result in the emission factors being "daily" averages are that the diurnal emissions are based on the user input minimum and maximum temperatures, and that the temperature used for correction of exhaust and other emission factors is based on a trip-weighted average (that is, the model uses a typical daily temperature profile and a national average distribution of VMT over the 24 hours of the day to estimate a single value of temperature that, when used to correct emissions, approximates the same result that would be obtained by estimating emission factors for each of 24 hourly temperatures and weighting those factors by the fraction of daily VMT occurring in each of the 24 hours). This is further discussed in an earlier EPA technical report.[17] When users seek emission factors for shorter time periods, such as hourly emissions needed for airshed modeling, the model can be instructed to correct all non-diurnal emission factors for the user input value of ambient temperature; however, there are no provisions for estimating diurnal emissions on an hourly basis.

Due to the increasing need on the part of some emission modelers to estimate emissions on an hourly basis, MOBILE6 is being developed to include the ability to provide both daily average emission factors (as is now done) and as hourly emission factors for each of the 24 hours of the day. The data from the real time diurnal testing, already discussed above, will be used to develop hourly diurnal emission rates. The user will be provided the option of supplying a daily minimum and maximum temperature, in which case the hourly temperatures will be calculated using the typical daily temperature profile already included in MOBILE5; or, or supplying 24 hourly temperatures, in which case the distribution of VMT over the 24 hours will be combined with these user-specified temperatures in order to calculate the daily average emission factors. Exhaust emissions and other categories of non-exhaust emissions will also be calculated on an hourly basis. Daily emissions will be calculated as a weighted sum of these hourly estimates.

Work on this aspect of MOBILE6 is still underway, and has not been completed to a point that would allow more detail to be provided at this time. As in other parts of the model that are still in relatively early stages of development, EPA will post any technical reports and other analyses in the MOBILE6 section of the OMS Web site as they are completed.

Input/Output changes

- Use of labeled input/elimination of control flags

Perhaps the biggest change in the MOBILE model from the perspective of the modeler preparing input data files is the planned elimination of the "control flags" and the use of labeled input. Rather than a set series of integer-valued flags specifying types of input data to be used, output items to be included, and the like, there will be a set of default assumptions made; if there is no contrary or supplementary information in the input file, these defaults will be used. This will have a number of benefits in terms of simplicity of data files, easing the preparation of the files, and assisting the modeler (and others) in reading and interpreting these files.

"Labeled input" refers to the ability of the MOBILE6 program to recognize certain characters or character strings and to operate accordingly. For example, the optional ability to have more detailed vehicle class factors provided in the output along with the more familiar eight vehicle class average emission factors was discussed above. In the absence of instructions, the model will produce eight average emission factors only. However, if a line is included in the input file that says "Heavy Duty Breakout" then the output will include both the standard eight average emission factors and emission factors for each of the heavy duty vehicle classes. Since the program will recognize this instruction no matter where in the input data file it appears, the use of labeled input will also eliminate the requirement that every component of the input file appear in a precisely specified ordering. Most input files for MOBILE6 will be considerably shorter than those used for earlier versions, as the file will only have to contain information that the modeler wishes to specify (that is, if the default is to be used for a specific aspect of the modeling, then no information relating to that aspect need appear in the input data file).

The use of labeled input will make reading and interpreting MOBILE6 input data files much easier than in the past. In addition, the modeler will have much more extensive abilities to document the input assumptions in the resulting output: Any line in the input data file that begins with an asterisk (*) in column 1 will be interpreted as a "comment," which will be read in and reprinted as part of the corresponding output file without having any impact on the calculations. Finally, the more complicated possible user inputs will be handled through the use of external data files, as described below.

Much remains to be determined with respect to the exact labels to be used, how much variation in labels will be permitted (that is, will still be recognized and correctly interpreted by the model), and other details. A more complete outline of the plans for MOBILE6 in this area was presented at the MOBILE6 public workshops held in Ann Arbor, MI in 1997. The

presentations made at those workshops are all available for review in the MOBILE6 section of the OMS Web site.

- External data files (e.g., fleet characteristics data)

Certain input data that is commonly used, but not always required, in estimating emission factors is particularly long and complex, and so is usually considered onerous to provide and interpret. The major examples of these types of input data are the specification of alternate registration distributions and annual mileage accumulation rates by age and vehicle type. In MOBILE6, these (and possibly other) types of input data will not appear directly in the input data file prepared for MOBILE6. Rather, they will be provided in external (to the model) data files, and only the location of the external data file will need to be provided in the MOBILE input file. This will provide two significant benefits to the modeler. First, the information (for example, the local registration distributions) will only have to be developed and formatted once; after that, any MOBILE runs that require inclusion of the alternate registration distributions will only have to note the name and location (file path) of that external file.

As in the case of the labeled input, there are still a number of details to be worked out in terms of exactly how this will be implemented in MOBILE6. An overview of the concept was presented at the 1997 MOBILE6 public workshops, and can be viewed at the OMS Web site. As EPA completes more work in this area, additional documentation will be posted there.

- Modified outputs (one descriptive, one electronic/database-type output)

MOBILE5 continued to provide the modeler with four options for the emission factor output reports, as had been done with earlier versions: a "short" and a "long" form of descriptive output, and a "short" and "long" form of numeric output. The descriptive output formats are intended for reading and interpretation by persons; they contained extensive labeling, echoing of input information, and other text enabling the reader to follow what was presented. The numeric outputs are intended to facilitate use of the output file as input to other programs; the labels and other text included are minimal, with the focus being on consistent columns of data so as to be read in by other programs.

Given the extensive changes being made, the improvements in computer hardware and software since MOBILE5 was developed, and EPA's understanding of the needs of the modeling community, we have decided against attempting to maintain all four of these output format choices for MOBILE6. Instead, attention is being focused on providing one high-quality, easily read and understood "descriptive" format, and one electronic (numeric) output. The descriptive output will be based on what is currently known as the "long" descriptive output format; it will be best viewed landscape style, and will include extensive, clear labeling of all information. Combined with the changes to the input files (labeled input, external data files), it should be easily read and interpreted, even without having the corresponding input file at hand. As noted, it will also contain echoing of all comments (lines starting with "*" in column 1) provided by the

preparer of the input data file.

The new electronic output is being developed in such a way as to be easily read into common database programs. The output will use ASCII characters making it also readable by spreadsheet programs, such as Lotus 1-2-3 and Excel, as well as to facilitate its input to other calculation programs that require highway vehicle emission factors, such as CALINE or CAL3QHC.

The precise details of how these two output reports will appear cannot be definitively specified until we are much closer to completing revisions to the model. Overviews of EPA's intent in this area were presented at the 1997 public workshops on MOBILE6, and are available for review at the OMS Web site. As we complete more work and more decisions on details in this area are made, additional information and documentation will be posted there.

Stakeholder and Peer Review

The development of revisions to the MOBILE model is a lengthy and involved process. In the past, the primary means by which OMS has involved its stakeholders in the process has been public workshops. At these workshops, OMS presents preliminary plans, analyses, and results, and seeks the input and reaction of attendees. While these workshops are open to the general public and announced in the Federal Register, the bulk of attendees have been representatives of the regulated industries (auto and engine manufacturers, petroleum companies, and trade associations for these industries), contractors, and model users (State and local air quality officials and staff, EPA Regional Office representatives). EPA has always encouraged attendees to submit comments on the materials presented at these workshops, and has considered those comments in further refinement and finalizing of model revisions.

However, considerable criticisms have been voiced that these workshops alone are inadequate to provide sufficient opportunities for affected parties to comment on revisions to the model and to influence its final form and content. In developing MOBILE6, OMS is taking unprecedented steps to provide more opportunities for interested parties to provide input to the model revision process. In addition to continuing to conduct public workshops, as we have done in the past, OMS has taken several other approaches to maximizing opportunities for comment on the model.

First, OMS has established an electronic list server devoted to news and information concerning mobile source emission factor development, revision, and use. This list server is used to disseminate information and guidance concerning the model and its use to all interested parties using computer based e-mail. Updates and corrections to the existing model, MOBILE5a, are issued over the list server, and guidance on using the model for specific applications is announced there. In addition, information concerning the development of MOBILE6 is sent over the list server, notably announcements that new material has been made available for review and comment by stakeholders. This stakeholder review process is discussed below.

Second, we have established a section within the OMS Web site, as has been noted earlier in this paper, devoted exclusively to MOBILE6 development and stakeholder review. As proposals are developed, analyses completed, and progress made on other aspects of the revised model, EPA posts reports and other materials on the Web site for stakeholder review. Formal reports are numbered to facilitate tracking of the material, and announcements of such postings are sent over the list server. Each report dealing with MOBILE6, when posted, provides a sixty day comment period during which comments are accepted from any interested individuals and organizations. This addresses the concerns that have been raised that in the workshop format, EPA only presents material that has largely been finalized, and the stakeholder review process provides earlier and more frequent chances for comment on proposals, preliminary results, and intended modeling approaches. All comments submitted as part of the stakeholder review process will be fully considered, and responses prepared and posted, before final changes are implemented in MOBILE6. More information about the stakeholder review process, means of submitting comments, and related information can be found at the Web site (http://www.epa.gov/oms/m6.htm).

Finally, EPA is obtaining formal peer review of most significant analyses and documentation intended for use in MOBILE6. While difficulties have been encountered in locating a sufficient pool of independent experts for reviewing components of the model, this process appears to be working, and is providing EPA with more and more independent reaction and comment than has been true in the past. The primary peer review coordinator for MOBILE6 analyses is Mr. Venkatesh Rao of the Assessment and Modeling Division. As with other related topics, additional information on peer review and its role in the development of MOBILE6 can be found in the modeling section of the OMS Web site.

The overall benefits of the list server and the expanded stakeholder and peer review processes are expected to be a more sound model, with greater confidence in the results provided by the model. Users of the model, and those who make decisions based in part on results of such modeling, will be able to have more confidence in the emission factors produced by MOBILE6, and hence in their decisions based on such modeling.

Summary

In many ways, MOBILE6 will be the most extensive revision of the highway vehicle emission factor model undertaken since MOBILE1. Virtually all emission rates and correction factors are being revised and updated, the structure of the input and output are being revised to account for changes both in the underlying analyses and assumptions used in the model and the expanding audience for use of the model, and the process for obtaining outside review and input is more extensive than has been attempted in the past. While MOBILE6 will not provide "the" answer to the question "What are the levels of emissions from highway vehicles in use?," and will not address every concern that has been raised by those using the model, we are confident that it will provide better, more accurate emission factor estimates than did earlier versions, and that those using these results will be able to have more confidence in them than in the past.

In the time remaining before MOBILE6 is finalized and released, the continued use of the current MOBILE5a and MOBILE5b models (as applicable) will be accepted by EPA for all analyses (including State Implementation Plan (SIP) inventories and other submittals). As in all cases where the MOBILE model is revised, there will be "transition issues" that will require EPA to develop and issue guidance covering the details of switching from use of the previous model to the new model. Such information will be disseminated over the list server discussed earlier, posted on the OMS Web site, and where appropriate announced in the Federal Register.

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