United States Environmental Protection Agency
Air and Radiation
EPA420-P-99-030
October 1999
M6.HDE.003

EPA

Development and Use of Heavy-Duty NOx Defeat Device Emission Effects for MOBILE5 and MOBILE 6

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Development and Use of Heavy-Duty Defeat Device Emission Effects for MOBILE5 AND MOBILE6

Report Number M6.HDE.003

October, 1999

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Introduction

This document describes the methodology used to estimate excess NOx emissions produced by heavy-duty diesel vehicles (HDDV) as the result of built-in defeat devices. Also, presented in the document are emission estimates based on two programs designed to mitigate the effect of the defeat device on fleet NOx emission levels. These include the incorporation of more stringent HDDV standards earlier than originally required (pull ahead), and accelerated engine rebuild programs (rebuild) to get in-use engines into better compliance. The document describes two basic models. The first model is an Excel spreadsheet model (Spreadsheet Model) used to calculate excess HDDV NOx emission effects in units of tons per year. Both a MOBILE6 and a MOBILE5 version of the spreadsheet model were developed. The excess NOx emission results in tons from this spreadsheet model are compared with the official EPA heavy-duty defeat device inventory emission results prepared by EPA’s Office of Compliance and Enforcement (OECA). The second model is the heavy-duty defeat device module that is built into the MOBILE6 emission factor model. It was developed and programmed into MOBILE6 using parameters from the spreadsheet model. The specific methodologies, parameters, procedures and their incorporation in the MOBILE6 model (the second model) are also discussed in this document.

The defeat device parameters were also incorporated in the MOBILE5 version of the Spreadsheet Model and into the MOBILE5 model because of the need to create a baseline comparison with MOBILE5 that included the emission effects of the defeat device . For example, the effects of the defeat device were incorporated in the MOBILE5 Spreadsheet Model to create Calendar Year (CY) 1990 or CY1995 baseline NOx inventories that included defeat device operation. A modified version of MOBILE5 that included the defeat device effects was also created so that consistency could be maintained between past baseline inventories made with MOBILE5 and future projections.

The MOBILE5 version of the defeat device spreadsheet model and the defeat device module that is built-in the MOBILE5 code is completely analogous to the MOBILE6 based spreadsheet model and code module. The only differences are in the data parameters. These parameters include the heavy-duty vehicle conversion factors, the basic heavy-duty vehicle NOx emission factors without the defeat device present, the VMT distribution by vehicle class, and the VMT distribution by model year. The only difference between the MOBILE6 and MOBILE5 values is that the MOBILE6 values are updated to account for more recent data collection by EPA.

For purposes of this modeling, a defeat device is a vehicle component or software which allows excess emissions to be produced during operating modes which are not explicitly covered by a certification test while still controlling emissions during the certification test. In the case of the heavy-duty NOx defeat device, the device was active (shut off emission control systems) during steady-state operating modes such as cruising down the freeway, but was mostly inactive during transient operation. It was built into heavy-duty diesel vehicles beginning in the 1988 model year, and completely removed by the 2000 model year. In the late 1980's and early 1990's the defeat device was being phased into the fleet and was mostly confined to the heavy end of the heavy-duty diesels (8a and 8b vehicles). However, by the mid to late 1990's it was widespread on virtually all of the heavy end engines and most of the medium and light end heavy-duty diesels.

This document is NOT a legal document, or an official emission inventory document. These official documents can be found in the official EPA Consent Decree documents and supporting material. This current document is merely an attempt to compile estimates of the impact of the defeat device, the proposed solutions from official sources, and fit it to the framework of the MOBILE6 model. These results may differ from the official EPA emission estimates in tons per year. A reader interested in the fleet impact of the defeat device based on official sources should refer to the official consent decree document.

This document is structured into three principal parts. The first part describes the structure, parameters, and use of the spreadsheet model. This part is composed of several sub-sections. These include a description of the model's overall structure, the data parameters of the model, the control parameters and a brief look at the results. The second part describes the implementation of the Spreadsheet Model outputs and parameters into the existing MOBILE6 model structure. An appendix at the end of the paper presents the FORTRAN code used to implement the algorithm. Currently, the code has not been fully integrated into the MOBILE6 model; thus, results are not available. The third section briefly describes (in a very limited way) the use of the MOBILE5 and MOBILE6 defeat device spreadsheet models to provide heavy-duty vehicle defeat device emission effects for subsequent inventory modeling.

1. Heavy-Duty Diesel Vehicle Defeat Device Spreadsheet Model

This section describes the overall structure, data parameters, and input / output structure of the HDDV defeat device spreadsheet model (spreadsheet model). The actual models are available at the EPA OMS website as an Excel spreadsheet entitled "DefeatM6.xls" - MOBILE6, and "DefeatM5.xls" - MOBILE5. Excel spreadsheets entitled "DDM6_Data.xls" and "DDM5_Data.xls" are also available that contains a summary of the important data parameters. Both of the data spreadsheets are in exactly the same format, and should be viewed as a companion to this text document.

1.1 Overview of the Basic Structure

The spreadsheet model is a calculator that weights the individual model year and vehicle class emission factors with vehicle miles traveled (VMT) inputs and sums these results into overall yearly excess NOx emission levels in tons. The following data parameters are used in the spreadsheet, and are defined in the subsequent sections. The term "MOBILE6/5" means MOBILE6 and MOBILE5.

MOBILE6/5 Heavy-Duty Vehicle Conversion Factors
MOBILE6/5 Basic Emission Factors WITHOUT Defeat Device Effects
Basic Emission Factors WITH Defeat Device Effects
Defeat Device Operating Parameter and Fleet Penetration Rates
Total HDDV Vehicle Miles Traveled (VMT)
MOBILE6/5 Distribution of VMT by Roadway Type, Vehicle Class and Model Year
MOBILE6/5 HDDV Speed Correction Factors

Several equations are used to weight together these parameters and sum the results. These equations are shown in the section labeled "Calculations".

1.2 Heavy-Duty Vehicle Conversion Factors

The HDDV conversion factors (CF) used in this model are shown in Excel Spreadsheet DDM6_Data.xls (or DDM5_Data.xls) in worksheet CF. These conversion factors were taken from MOBILE6 (or MOBILE5) and are referenced in EPA report "Update Heavy-Duty Engine Emission Conversion Factors for MOBILE6: Analysis of BSFCs and Calculation of Heavy-Duty Engine Emission Conversion Factors" - EPA420-P-98-015. The conversion factors are used to convert the basic heavy-duty diesel emission factors from g/bhp-hr into g/mi units. This is necessary so that the four individual heavy-duty diesel vehicle class emission factors and the individual roadway factors can be properly weighted together by VMT. Emission factors in units of g/bhp-hr cannot be VMT weighted because the basis units are in bhp-hr rather than in miles. The analogous conversion factors for the MOBILE5 model were taken from the MOBILE5 source code.

The conversion factors are shown as a function of model year and vehicle class. The model years range from 1964 through 2030. Each column in the worksheet CF contains a conversion factor for one of the four heavy-duty vehicle classes: Light, Medium, Class 8a and Class8b. In all cases, the Light class conversion factors are composite values obtained by weighting the individual sub-classes (light-heavy duty standard classes of 2b, 3, 4 and 5) together with the Bus conversion factors based on VMT. This was done because neither the Light or Bus class contain defeat device effects in any appreciable quantity.

1.3 MOBILE6 Basic Emission Factors WITHOUT Defeat Device Effects

The basic emission factors without defeat device effects used in the spreadsheet model are shown in Excel Spreadsheet DDM6_Data.xls (or DDM5_Data.xls) in worksheet BEFs. These are the base emission levels for a particular model year and vehicle class if the defeat device is not present or not working. The first five columns show the Without Defeat Device Emission factors. These are shown as a function of vehicle class (Light, Medium, 8a and 8b), and as a function of model year. Basic emission factors are shown for model years 1964 through 2030, and are in units of grams per brake-horsepower-hr (g/bhp-hr or g/hp-hr). These values are the default emission levels for HDDVs in MOBILE6, and are very heavily based on certification test results. The analogous MOBILE5 values are also default emission levels and are based on certification test results. The reference for the MOBILE6 values is EPA report EPA420-R-99-010 - “Update of Heavy-Duty Emission Levels (Model Years 1988 - 2004+) for Use in MOBILE6." The MOBILE5 values were taken from the MOBILE5 model code.

1.4 MOBILE6 Basic Emission Factors WITH Defeat Device Effects

The last four columns in worksheet BEFs of the Excel Spreadsheet DDM6_Data.xls (or DDM5_Data.xls) show the basic NOx emission factors in g/bhp-hr units when the defeat device is active and operating. Like the WITHOUT defeat device emission levels, the WITH defeat emission levels are shown as a function of vehicle class and model year. The same WITH defeat device emission levels are used in both the MOBILE5 and MOBILE6 spreadsheet model version. The “Light-Duty” class is unaffected by the defeat device so it shows the same NOx emission factors for both “WITH” and “WITHOUT” defeat devices. NOx emission factors are shown for the model year range of 1964 through 2030. One exception is the WITH defeat device NOx emission factors for model years 2002 and 2003. These are lower than the WITHOUT defeat device emission levels as the result of “Pull Ahead” requirements for lower certification standards. For model years 2004 and later, and model years 1987 and earlier, the WITH and WITHOUT defeat device emission levels are equivalent, since there would be no defeat device effects on emissions for these model year engines.

The defeat device emission effects were determined on an engine by engine basis using available data and engineering judgement by experts familiar with engine control software. These individual estimates were weighted together by engine family using diesel vehicle sales information to produce model year average emission levels (this document uses a summary of the individual manufacturer results). The individual engine family or manufacturer specific engine control logic, emission results and sales projections are proprietary in nature and were made available to the EPA on a confidential basis as part of the Heavy-Duty Diesel Defeat Device Consent Decree. Thus, they are not provided in this document nor are they publically available in any other source.

1.5 Defeat Device Operating Parameter and Fleet Penetration Rates

The defeat device operating parameters and fleet penetration rates used in the spreadsheet model are shown in worksheet "Fleet Fractions" of Excel Spreadsheet DDM6_Data.xls (or DDM5_Data.xls). These are shown as a function of vehicle class (light, medium, 8a and 8b), model year, and roadway type. The three roadway types are Urban, Arterial, and Interstate. There are four sub-types within each of these three broad classes, and they are also listed in spreadsheet DD_Data.xls worksheet "Fleet Fractions." The Urban type represents city driving which includes considerable stop-and-go transient operation. The Arterial type represents driving on primary roads in which there is both transient operation and steady-state operation. The Interstate type represents the operation which includes mostly steady state type driving at higher speeds. A zero (0.00) means that the defeat device does not operate during that mode, and a one (1.00) would mean that it operates all of the time in that mode. This information is on a fleet summary basis. It was calculated from individual engine family defeat device response data that was determined from proprietary and confidential data submitted by the engine manufacturers, limited testing of affected engines, and engineering judgment by experts in engine control and emission control software. As a general rule, the Urban type contains relatively little defeat device operation, and the Interstate type contains considerable defeat device operation, as can be seen in the low fractions for Urban and the high fractions for Interstate. The defeat device operating fractions are also a function of model year.

The columns entitled "Fleet Fraction" show the percent of a particular model year and vehicle class that is equipped with the defeat device or affected by the legal settlement. A value of zero means for that particular combination of vehicle class and model there are no defeat devices, and a value of unity (1.0) means that in that model year, all vehicles of that class were equipped with defeat devices. In general, the data suggests that the defeat device penetration began slowly in the 1988 model year on the heavier class diesels, and slowly progressed to encompass most of the fleet. Virtually full penetration seems to have occurred by the mid 1990's on the heavier engines. Penetration drops off abruptly around calendar year 2000, presumably due to the settlement. The only exception to this rule is for the case of the 2002 and 2003 model years. These model year groups contain a coded factor to calculate the impact of "Pull Ahead." No defeat devices will be produced in those model years. The MOBILE6 With Defeat Device operating parameters and fleet penetration rates were used in the MOBILE5 version directly.

1.6 Total VMT Estimates

The Total VMT Estimates are shown in worksheet Total_VMT of Spreadsheet

DDM6_Data.xls (or DDM5_Data.xls). Separate values are shown for calendar years 1988 through 2010. The VMT values were obtained from the EPA Trends model, and are typical HDDV VMT levels used in Air Quality modeling. Linear equations are used to project future VMT levels. The Total VMT estimate is an important factor in determining the total tons of NOx produced by the defeat devices. However, it is not explicitly used in the MOBILE6 model inputs because MOBILE6 does not produce NOx emissions in units of tons (only in grams per mile). The same Total VMT estimates were used for both the MOBILE6 and MOBILE5 models.

1.7 Distribution of VMT by Roadway Type, Vehicle Class and Model Year

1.7.1 Distribution of VMT by Roadway Type

The VMT distribution by Roadway Type used in the spreadsheet model is shown in worksheet "Road_VMTDist" of Excel Spreadsheet DDM6_Data.xls (or DDM5_Data.xls). In general, there are three basic facility types - Urban, Arterial and Interstate. Within each of these three basic types, there are four individual roadway types (a total of 12 roadway types). The VMT weighted distribution for each roadway type by vehicle class is shown at the top of worksheet Road_VMTDist. These values were obtained from the report "Documentation of Mobile Source Inventories Used in OAQPS Trends Report" by EH Pechan under EPA Contract 68-D3-0035. They are used to properly weight the impact of the defeat device by vehicle class for each of the 12 roadway types. The values for the VMT distribution by roadway type were used in both the MOBILE6 and MOBILE5 versions.

1.7.2 Distribution of VMT by Vehicle Class

The next small table in the worksheet Road_VMTDist of DDM6_Data.xls (or DDM5_Data.xls) contains the vehicle class distribution, which distributes VMT by vehicle class. It is combined with the defeat device roadway distribution, to create a VMT distribution by roadway type and vehicle class. Different values were used for the MOBILE5 spreadsheet model. The MOBILE5 values contained a somewhat higher fraction of VMT allocated to the 8a class of heavy-duty diesel vehicle, and thus accounted for one of the biggest differences between the MOBILE6 and MOBILE5 NOx defeat device inventories.

1.7.3 Distribution of VMT by Vehicle Class and Roadway

The table at the bottom of Road_VMTDist is a combined VMT distribution by Vehicle Class and Roadway type. It is the product of the previous two tables and is used directly in the calculation of defeat device effects. Mathematically, each row in the table sums to unity for a given roadway type. Different values are computed for the MOBILE6 and MOBILE5 models due to the different

VMT distribution by vehicle class.

1.7.4 Distribution of VMT by Model Year

The VMT distribution by age and vehicle class used in the spreadsheet model is shown in worksheet "TF" of Excel Spreadsheets DDM6_Data.xls and DDM5_Data.xls. The TF represents Travel Fraction, and is used to distribute the defeat device emission effects by model year / age. The values are the standard MOBILE6 travel fractions calculated from MOBILE6 parameters such as diesel fleet penetration, annual mileage accumulation rates by vehicle class, and registration distributions by vehicle class. The primary reference for these parameters is EPA report "Update of Heavy-Duty Emission Levels (Model Years 1988 - 2004+) for Use in MOBILE6" - EPA report EPA420-R-99-010. The MOBILE5 distribution was taken from the MOBILE5 computer code. It differs from the MOBILE6 distribution because it is a single distribution that represents all four of the vehicle classes; whereas, for MOBILE6, separate age distributions are used for each of the four vehicle classes.

1.8 MOBILE6/5 HDDV Speed Correction Factors

An average speed is associated with each of the twelve roadway types. The average speed information was obtained from the report "Documentation of Mobile Source Inventories Used in OAQPS Trends Report" by EH Pechan under EPA Contract 68-D3-0035. The twelve roadway types and the average speeds are listed below in Table 1. The letters I, A and U in parentheses stand for Interstate, Arterial and Urban, respectively. These average speeds are based on an analysis EH Pechan did in 1991 on DOT data.

In this analysis, speed correction factors are used only to model the effect of speed on the heavy-duty emissions which are associated with "without defeat device operation." The "with defeat device heavy-duty emission factors" implicitly contain speed correction factors, and need no additional speed correction. This implicit relationship is an assumption that the defeat device emission effects inherently contain all of the remaining speed related NOx emission effects that occur as the result of vehicle operation outside of the certification test cycle, and the certification cycle's average speed of 20 MPH. The basis for this assumption is that the defeat device effects are a strong function of speed and typically only occur during the steady-state higher speed activity of the trucks. Also, based on the limited test and engineering data, it is not feasible to separate defeat device NOx emission effects from normal speed correction NOx emission effects.

The average speed for each roadway type is used to calculate the NOx speed correction factors. The speed correction factor equation used in this analysis is the standard MOBILE5/6 equation for heavy-duty diesels (the same value is used in both MOBILE6 and MOBILE5. It is not a function of roadway type. The speed correction factors are calculated for each of the roadway types by inserting the appropriate average speed into Equation 1 below:

$$\text{NOx Speed CF} = 0.676 - 0.0480*\text{speed} + 0.00071*\text{speed}**2 \qquad \text{Eqn 1}$$

‘**2' means squared.

Table 1 **Roadway Types and Average Speeds**	
Roadway Number and Name	**Average Speed (MPH)**
1. Rural Interstate (I)	40
2. Rural Other Principal Arterial (I)	35
3. Urban Interstate (I)	35
4. Urban Freeway & Expressway (I)	35
5. Rural Minor Arterial (A)	30
6. Rural Major Collector (A)	25
7. Rural Minor Collector (A)	25
8. Rural Local (A)	25
9. Urban Other Principal Arterial (U)	15
10. Urban Minor Arterial (U)	15
11. Urban Collector (U)	15
12. Urban Local (U)	15

1.9 Calculations

1.9.1 With Defeat Device Emission Calculation

The calculations in the spreadsheet model DefeatM6.xls (or DefeatM5.xls) are fairly simple and straightforward in concept, although quite voluminous due to the need to duplicate them twice for each of the twelve roadway types (24 times). The following general method and equations were used:

1. The Without Defeat Device emission factors are speed corrected, but the With Defeat Device are not speed corrected because the defeat device inherently contains NOx speed effects.

2. The speed correction factor was calculated using Equation 1 and the appropriate speed from Table 1.

3. For each model year, roadway type, and vehicle class, Equation 2 is used to calculate a basic

fleet emission factor that is a weighted average of the With and Without defeat device rates.

Fleet = [NO_DD*(1-DD_equip)*SpeedCF + NO_DD*DD_equip*(1-DDmode)*SpeedCF + DD*DD_equip*DDmode] * CF   Eqn 2

Where:

NO_DD is the basic emission factor if no defeat device is present (from worksheet BEFs of DD_Data.xls).

DD is the basic emission factor if a defeat device is present and operating (from worksheet BEFs of DD_Data.xls).

DD_equip is the fraction of the fleet which has a defeat device installed on it (from worksheet Fleet Fractions of DD_Data.xls).

DD_mode is the VMT fraction in a given roadway type mode that the defeat device is in operation (from worksheet Fleet Fractions of DD_Data.xls).

SpeedCF is the appropriate speed correction factor for the given roadway number (calculated from Equation 1).

CF is the appropriate heavy-duty conversion factor to convert the emission rate in grams/bhp-hr into grams/mile. It is a function of vehicle class (from worksheet CF of DD_Data.xls).

Fleet is the fleet average NOx emission level with defeat devices for a given roadway type mode and model year in units of g/mile

1.9.2 Without Defeat Device Emission Calculation

The Without Defeat Device emission calculation is analogous to the With Defeat Device calculation. Equation 3 is used to calculate the NOx emission level for a particular permutation of roadway, model year, vehicle class and speed.

The Without Defeat Device emission factor is speed corrected using the appropriate speed correction factor for a given roadway number. Equation 1 is multiplied by the Without Defeat Device basic emission factors found in DD_Data.xls sheet BEFs.

$$Fleet2 = [NO\_DD * SpeedCF * CF] \quad \text{Eqn 3}$$

NO_DD is the emission factor if no defeat device is present.

SpeedCF is the appropriate speed correction factor.

CF is the appropriate heavy-duty conversion factor to convert the emission rate into grams/mile. It is a function of vehicle class.

Fleet2 is the fleet average NOx emission level without defeat devices for a given mode and model year in units of g/mile

1.9.3 <u>Overall NOx Defeat Device Tons</u>

The defeat device spreadsheet model found in DefeatM6.xls and DefeatM5.xls calculates total excess NOx tons for a given calendar year and other inputs. The model only calculates the excess NOx tons for a speed of 20 mph. The calculation procedure is described below using Equations 4, 5 and 6. The values in brackets are parameters for the value. For example, Fleet is a function of vehicle class (icls), roadway type (iroad), and model year (imy).

$$DD(icls,iroad,imy) = Fleet(icls,iroad,imy) - Fleet2(icls,iroad,imy) \quad \text{Eqn 4}$$

Where:

DD(icls,iroad,imy) is the net defeat device NOx emission effect for each combination of vehicle class(light, medium, 8a and 8b), roadway type(12 types), and model year.

Fleet(icls,iroad,imy) is the With Defeat Device NOx emission level for each vehicle class, roadway type, and model year calculated using Equation 2.

Fleet2(icls,iroad,imy) is the Without Defeat Device NOx emission level for each vehicle class, roadway type, and model year calculated using Equation 3.

The total HDDV excess NOx emissions in tons for a given calendar year are calculated using Equation 5.

$$DD\_Tons = \sum [DD(icls,iroad,imy)*TF(icls,imy)*TotalVMT(iroad,icls)*Constant] \quad \text{Eqn 5}$$

Where:

The summation is over the four vehicle classes (light, medium, 8a and 8b).

DD(icls,iroad,imy) the net defeat device effect calculated from Equation 4.

TF(icls,imy) is the model year VMT distribution for each vehicle class.

TotalVMT(iroad,icls) is the total VMT in millions of miles for a given combination of roadway type and vehicle class.

Constant contains the conversion factors from grams to tons per calendar year.

1.10 Rebuild Program Inputs to the Excess NOx Emission Spreadsheet Model

Most heavy-duty diesel engines are rebuilt after their initial useful life has elapsed. Typically, this occurs around the 350,000 mile point, and often includes replacing engine parts that affect NOx emissions. The practice of rebuilding is considerably more cost-effective to the truck owner than scrapping the engine. Because the rebuild practice is so widespread, the engine manufacturing industry agreed as part of the Consent Decree to rebuild a portion of the fleet in such a way as to reduce the effect of the defeat device on rebuilt engines. This NOx excess spreadsheet model will reflect the effects of the rebuild program.

The following parameters are defined and used in the MOBILE6 and MOBILE5 spreadsheet models to account for rebuilds.

Rebuild Fraction - This is the fraction of the eligible fleet that will be rebuilt. Currently this fraction is assumed to be 0.90.

Model Year Range - Two options were available in the consent decree. The one which is modeled in the spreadsheet model includes only the 1994 through 1998 model years. The other rebuild option (not modeled) includes the 1993 model year.

After Rebuild Emission Level - This is the NOx emission level that the rebuilt engines will emit in units of g/bhp-hr, and is set equal to 7.00 g/bhp-hr. The other rebuild option (not modeled) in the consent decree set this level at 7.50 g/bhp-hr. These were conservative values because the consent decree set these standards as “not-to-exceed” levels.

Years of Use Before Rebuild - This is the number of years prior to the first rebuild.
12 years for a medium duty
5 years for a 8a truck

3 years for a 8b truck

Also, no rebuild credit is given before calendar year 2000. Thus, a 1994 model year 8b engine will not be lowered to the 7.00 g/bhp-hr standard upon its first rebuild in 1997.

The effects of rebuild are implemented in the model by replacing the With Defeat Device Emission levels with the rebuild emission level of 7.00 g/bhp-hr on the fraction of the fleet that is rebuilt. The default value for the fraction of the fleet that is rebuilt is 90% of the 1994 through 1998 model years.

1.11 MOBILE6 Model Results

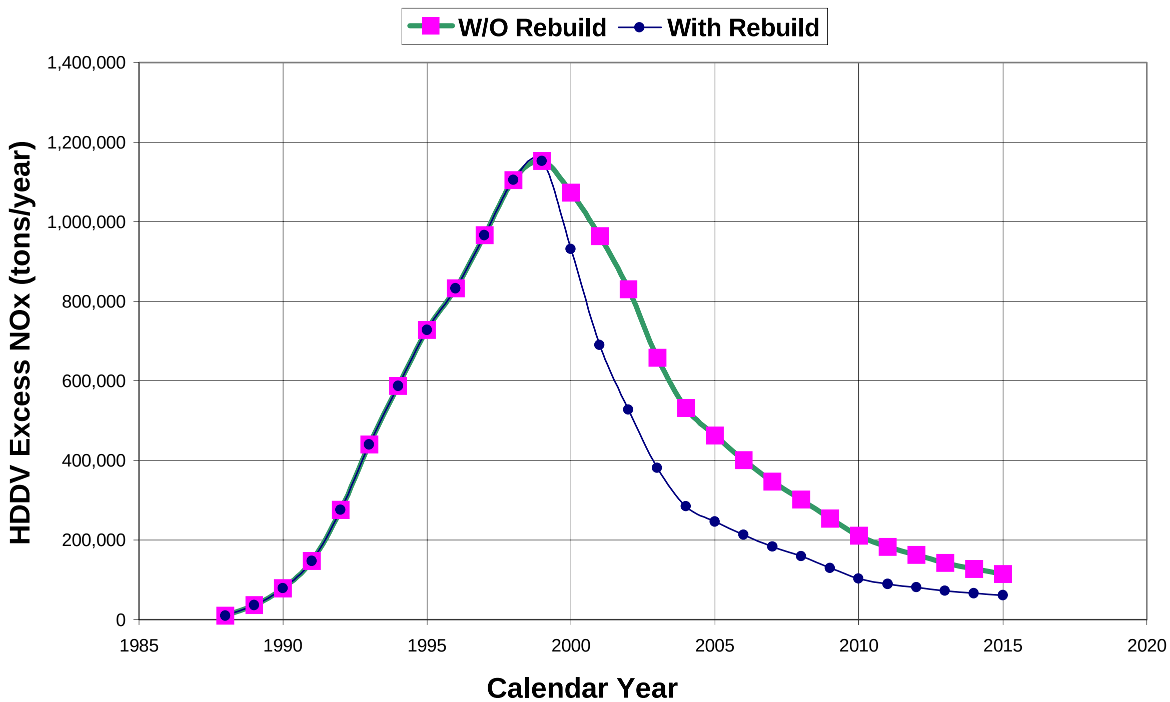
This section presents the overall NOx excess emission results in tons per calendar year from the MOBILE6 based Spreadsheet model. Figure 1 shows the excess NOx emissions for a range of calendar years with and without the effects of rebuilding the 1994 through 1998 model year engines. The effect of "Pull Ahead" is present in both the With and Without rebuild curves.

Figure 2 shows a comparison of the MOBILE6 Spreadsheet model excess NOx emission results with the original EPA Office of Enforcement Model (OECA Model). The differences between the two models in terms total excess NOx tons stems from a difference in approach and the use of different basic parameters. This difference is sizable for some calendar years between 1995 and 2000.

The approach taken for the two models is somewhat different. The OECA model starts with basic NOx emission and market share information on each engine family, and weights these together by market share, defeat device penetration within a given engine family, vehicle scrappage rates, and VMT information. These weighted NOx emission values for each engine family are then summed together on a calendar year basis to produce the fleet NOx excess emission totals in tons. Because of the proprietary nature of many of these inputs such as projected market share for individual engine manufacturer and individual engine families, neither this model or its data parameters can be released. The OECA model also reports only the increase in fleet NOx emissions due to the defeat device by calendar year. No model year specific results are possible. It also does not include a heavy-duty vehicle fleet estimate of NOx emissions if no defeat device were present (base level), nor does it provide a combined base and defeat device fleet emission level in tons by calendar year.

The approach taken for the Spreadsheet models (MOBILE6 and MOBILE5) is different from the OECA model. Instead of summing the individual engine family contributions to the total excess NOx emission level, these individual engine family parameters (emission level, operation in defeat device by roadway type, and penetration of defeat device) were combined into fleet average values by model year and vehicle class using fleet average sales and projected sales information. The actual and projected sales numbers were generally consistent between the OECA and M6/M5 Spreadsheet models; however, discrepancies arose when aggregating specific engine information into fleet average vehicle information segregated into the four heavy-duty diesel vehicle classes. Recent model year sales and future projected sales were the most problematic. The Spreadsheet model also contains Without defeat device (base) emission levels by model year. These are from the MOBILE6/5 heavy-duty vehicle data parameters. For the MOBILE6 Spreadsheet model, the NOx emission effect of the defeat device is essentially the difference between the With and Without Defeat Device emission factors. The final With defeat device emission levels and the Without defeat device emission levels are shown in worksheet BEFs of DDM6_Data.xls. The process used to

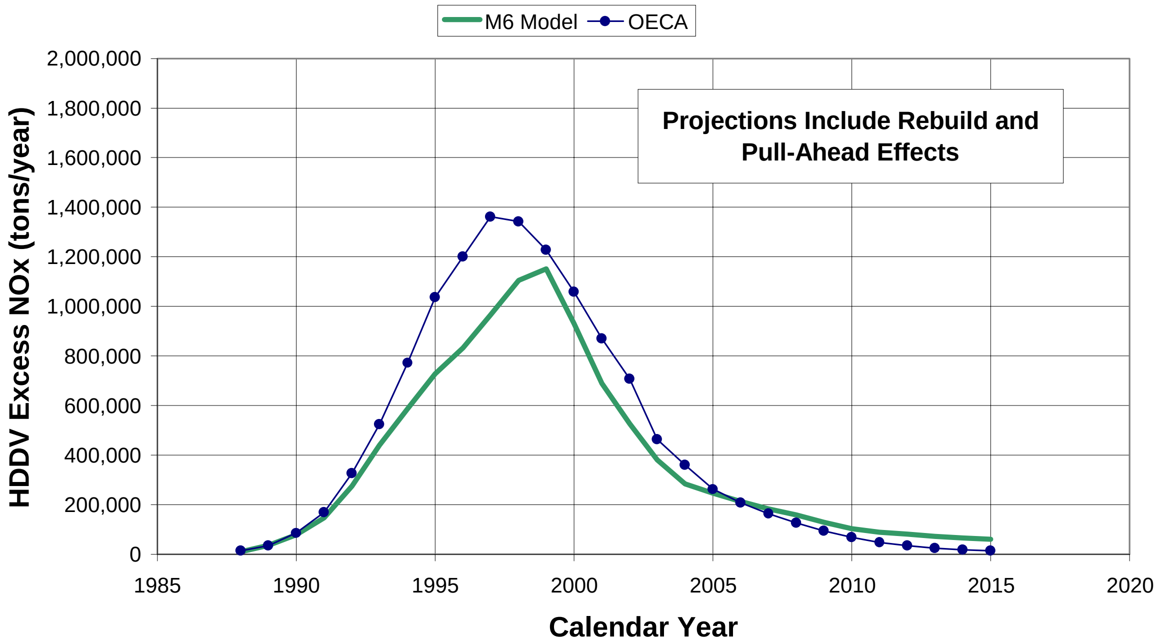
Figure 1
Heavy-duty Diesel Vehicle Excess NOx by Calendar Year



develop the "With Defeat Device" fleet average emission levels by model year is not shown due restrictions on publishing proprietary data.

The MOBILE6 Spreadsheet model and the OECA model also differ in the data parameters that were used to build the models. The Spreadsheet model uses MOBILE6 emission and VMT parameters, while the OECA model uses some MOBILE5 based parameters. These include different conversion factors (CF), different VMT distribution by vehicle class, and different total VMT levels.

Figure 2
Heavy-duty Diesel Vehicle Excess NOx Projections
Comparison of MOBILE6 and OECA Model Approaches



2.0 Defeat Device Model Implementation in FORTRAN

This brief section and the following Appendix discuss the integration of the HDDV defeat device NOx emission spreadsheet model into the MOBILE6 code. It is presented in this document for readers who are interested in seeing the exact code. This may be important since the Spreadsheet model will not produce results in the same units as the MOBILE6 defeat device implementation. During this integration, every attempt was made to preserve as much continuity between the two models as possible. However, this was not always possible since MOBILE6 reports emissions as emission factors in units of grams per mile while the spreadsheet model produced an emission result in terms of tons. Because of this basic difference, perfect agreement will never be attained between the two models.

The primary difference between the two models is the use of VMT to weight different vehicle classes, roadway types, and model years together. MOBILE6 generally will not use these parameters since the output is in terms of grams per mile for specific vehicle classes, roadway types, and model years. When the MOBILE6 model is called to produce average gram per mile emission factors that include a number of model years, vehicle classes or roadway types, the same VMT parameters will be used as presented earlier in this document in Section 1.0. The list of parameters which overlap between the two models are the Conversion Factors and the speed correction factors.

The basic HDDV NOx excess emission factors which are used in MOBILE6 are the difference between the With and Without defeat device emission levels. These delta emission values (difference between With and Without Defeat Device) are analogous to the values calculated in Equation 4, and are in units of g/mi. They can be found in the MOBILE6 BLOCK DATA in Module DDNOBD in array NEFFCT. Also, found in Module DDNOBD are the defeat device operating parameters and the fleet penetration rates.

The basic defeat device data and other parameters are utilized in subroutine "Defeat" This subroutine takes the basic emission and defeat device operating parameters and calculates a new average fleet NOx emission level for MOBILE6 that includes the effect of the defeat device for the various roadway types, affected model years, calendar years, and vehicle classes.

3.0 Use of the MOBILE6 and MOBILE5 Spreadsheet Models

The MOBILE6 and MOBILE5 Heavy-duty Diesel Vehicle NOx Defeat Device Spreadsheet models (Spreadsheet Model) were used in four emission inventory and air quality applications to model the NOx emissions associated with the heavy-duty defeat device. These applications are:

1. Regional Ozone Transport Rule (ROTR)
2. Revised Regional Ozone Transport Rule (RROTR)
3. Tier2 Rulemaking (Tier2)
4. Southern Appalachian Ozone Modeling (SAOM)

In all four of these cases, the output of the Spreadsheet model that was used in subsequent modeling were ratios of "With Defeat Device" NOx emissions and "Without Defeat Device" NOx emissions for various calendar years, roadway types, and speeds. For all cases, separate ratios were computed for each of the twelve roadway types, and for thirteen different speeds (in five mile per hour increments) ranging from 5 MPH to 65 MPH. A set of these ratios was generated for a series of calendar years that included CY1995 and CY1996 as a baseline, and CY2004, CY2007 and CY2010. For both the MOBILE6 and MOBILE5 Spreadsheet models, the ratios can be found in the sub-worksheet DD_Summary.

The four individual applications also differed in their requirements for the ratios. The ratios that were computed for the ROTR were MOBILE5 With Defeat Device NOx (numerator) over MOBILE5 Without Defeat Device NOx (denominator). These ratios include the effects of "Pull Ahead," but did not include "Engine Rebuild Effects" in the With Defeat Device NOx levels. The ratios that were computed for the RROTR were MOBILE5 With Defeat Device NOx over MOBILE5 Without Defeat Device NOx , including the effects of "Pull Ahead," and the "Engine Rebuild Effects" in the numerator. The ratios that were computed for the Tier2 rulemaking were MOBILE6 With Defeat Device NOx over MOBILE5 Without Defeat Device NOx. These ratios include both the effects of "Pull Ahead," and the "Engine Rebuild Effects" in the numerator. Finally, the ratios that were computed for the SAOM work were MOBILE6 With Defeat Device NOx over MOBILE5 Without Defeat Device NOx. However, these ratios did not include the effects of "Pull Ahead," or the "Engine Rebuild Effects."

Figure 3 shows a set of With and Without Defeat Device Ratios for Calendar Year 2010. It includes both Rebuild and Pull Ahead provisions. The ratios are the MOBILE6 With Defeat Device Emission Factors over the MOBILE5 Without Defeat Device Emission Factors. In general, the ratios are typically 1.0 or less. The small numbers reflect relatively little defeat device activity in CY2010, and the relative difference between MOBILE6 parameters and MOBILE5 parameters such as CF, TF, Basic Emission Rates, and VMT distributions. Ratios less than 1.0 can occur due to differences between MOBILE6 and MOBILE5 and as the result of "Pull Ahead." They occur when MOBILE6 parameters produce lower excess NOx emission levels than analogous MOBILE5 parameters.

Figure 4 shows a similar set of With and Without Defeat Device Ratios for Calendar Year 2007. It also includes both Rebuild and Pull Ahead provisions. However, in Figure 4 both the numerator and the denominator are both based on MOBILE6. These ratios clearly isolate the effect of the defeat device, and suggest that it can be as high as 20 to 30 percent of the CY 2007 fleet for some roadways.

TABLE 3

Facility	Description	Roadway #	2010 Fleet w DD Speed 5	2010 Fleet w DD Speed 10	2010 Fleet w DD Speed 15	2010 Fleet w DD Speed 20	2010 Fleet w DD Speed 25	2010 Fleet w DD Speed 30	2010 Fleet w DD Speed 35	2010 Fleet w DD Speed 40	2010 Fleet w DD Speed 45	2010 Fleet w DD Speed 50	2010 Fleet w DD Speed 55	2010 Fleet w DD Speed 60	2010 Fleet w DD Speed 65
Interstate	Rural Interstate	1	0.8803	0.9253	0.9685	1.0062	1.0350	1.0521	1.0557	1.0455	1.0225	0.9890	0.9483	0.9038	0.8591
Interstate	Rural Other Prin Arterial	2	0.8803	0.9253	0.9685	1.0062	1.0350	1.0522	1.0558	1.0456	1.0225	0.9891	0.9483	0.9038	0.8591
Interstate	Urban Interstate	3	0.8805	0.9257	0.9691	1.0070	1.0360	1.0532	1.0568	1.0466	1.0234	0.9898	0.9488	0.9041	0.8591
Interstate	Urban Other Freeways	4	0.8804	0.9255	0.9687	1.0065	1.0353	1.0525	1.0561	1.0459	1.0228	0.9893	0.9485	0.9039	0.8591
Arterial	Rural Minor Arterial	5	0.8591	0.8724	0.8851	0.8963	0.9048	0.9099	0.9110	0.9079	0.9011	0.8912	0.8792	0.8660	0.8528
Arterial	Rural Major Collector	6	0.8592	0.8725	0.8853	0.8964	0.9050	0.9100	0.9111	0.9081	0.9013	0.8914	0.8793	0.8662	0.8529
Arterial	Rural Minor Collector	7	0.8599	0.8730	0.8856	0.8967	0.9051	0.9101	0.9111	0.9082	0.9014	0.8916	0.8797	0.8667	0.8537
Arterial	Rural Local	8	0.8585	0.8718	0.8846	0.8958	0.9043	0.9094	0.9105	0.9074	0.9006	0.8907	0.8786	0.8654	0.8522
Urban	Urban Other Prin Arterial	9	0.8319	0.8325	0.8332	0.8338	0.8342	0.8344	0.8345	0.8343	0.8340	0.8335	0.8329	0.8322	0.8315
Urban	Urban Minor Arterial	10	0.8325	0.8332	0.8338	0.8344	0.8348	0.8351	0.8351	0.8350	0.8346	0.8341	0.8335	0.8329	0.8322
Urban	Urban Collector	11	0.8297	0.8304	0.8311	0.8316	0.8321	0.8323	0.8324	0.8322	0.8319	0.8314	0.8308	0.8301	0.8294
Urban	Urban Local	12	0.8321	0.8328	0.8335	0.8340	0.8345	0.8347	0.8348	0.8346	0.8343	0.8338	0.8332	0.8325	0.8318

TABLE 4

Facility	Description	Roadway #	2007 Fleet w DD Speed 5	2007 Fleet w DD Speed 10	2007 Fleet w DD Speed 15	2007 Fleet w DD Speed 20	2007 Fleet w DD Speed 25	2007 Fleet w DD Speed 30	2007 Fleet w DD Speed 35	2007 Fleet w DD Speed 40	2007 Fleet w DD Speed 45	2007 Fleet w DD Speed 50	2007 Fleet w DD Speed 55	2007 Fleet w DD Speed 60	2007 Fleet w DD Speed 65
Interstate	Rural Interstate	1	0.8623	0.9233	0.9818	1.0329	1.0720	1.0952	1.1001	1.0863	1.0550	1.0097	0.9544	0.8941	0.8335
Interstate	Rural Other Prin Arterial	2	0.8623	0.9233	0.9818	1.0330	1.0721	1.0953	1.1002	1.0863	1.0551	1.0097	0.9544	0.8942	0.8335
Interstate	Urban Interstate	3	0.8626	0.9239	0.9827	1.0341	1.0733	1.0967	1.1016	1.0877	1.0563	1.0107	0.9551	0.8946	0.8336
Interstate	Urban Other Freeways	4	0.8624	0.9235	0.9821	1.0333	1.0724	1.0957	1.1006	1.0867	1.0555	1.0100	0.9546	0.8943	0.8335
Arterial	Rural Minor Arterial	5	0.8398	0.8583	0.8760	0.8915	0.9034	0.9104	0.9119	0.9077	0.8982	0.8845	0.8677	0.8495	0.8311
Arterial	Rural Major Collector	6	0.8399	0.8584	0.8761	0.8916	0.9035	0.9105	0.9120	0.9078	0.8983	0.8846	0.8678	0.8496	0.8312
Arterial	Rural Minor Collector	7	0.8406	0.8589	0.8764	0.8917	0.9034	0.9104	0.9118	0.9077	0.8983	0.8847	0.8682	0.8501	0.8320
Arterial	Rural Local	8	0.8394	0.8579	0.8757	0.8912	0.9031	0.9102	0.9117	0.9074	0.8980	0.8842	0.8674	0.8491	0.8306
Urban	Urban Other Prin Arterial	9	0.8189	0.8199	0.8208	0.8216	0.8222	0.8226	0.8227	0.8225	0.8220	0.8212	0.8204	0.8194	0.8184
Urban	Urban Minor Arterial	10	0.8194	0.8204	0.8213	0.8221	0.8227	0.8231	0.8232	0.8230	0.8225	0.8218	0.8209	0.8199	0.8190
Urban	Urban Collector	11	0.8170	0.8179	0.8189	0.8197	0.8203	0.8207	0.8208	0.8205	0.8200	0.8193	0.8184	0.8175	0.8165
Urban	Urban Local	12	0.8190	0.8199	0.8209	0.8217	0.8223	0.8227	0.8228	0.8225	0.8220	0.8213	0.8204	0.8195	0.8185

Appendix

FORTRAN Code Used to Implement the Defeat Device Emission Effects in MOBILE6

```
      SUBROUTINE DEFEAT(MY,ICY,IV,IROAD,IPULL,IBUILD,VVHDDV,RBLEV,DDNOX)
C
C
C..Rebuild modeling options using variable IBUILD.
C    IBUILD = 0  -  Default option - Rebuild effects are included at a
C                                    90% penetration for MY 1993-98
C    IBUILD = 1  -  No Rebuild effects are included.
C    IBUILD = 2  -  Rebuild effects are included for MY 1993-98 at a
C                   user specified level (RBLEV).
C
C    IPULL = 0   -  Default option - Pull ahead effects are included for
C                   MY 2002 and 2003. Negative emission increases.
C    IPULL = 1   -  Pull ahead effects are not included for MY 2002 and
C                   2003.  Defeat Device Effects are 0.0.
C
      USE DDDATA
C
      IMPLICIT NONE
C
      INTEGER, INTENT(IN) :: MY
      INTEGER, INTENT(IN) :: ICY
      INTEGER, INTENT(IN) :: IV
      INTEGER, INTENT(IN) :: IROAD
      INTEGER, INTENT(IN) :: IPULL
      INTEGER, INTENT(IN) :: IBUILD
      INTEGER, INTENT(IN) :: VVHDDV

      INTEGER :: IMY, IVV                          ! Local variables
C
      REAL, INTENT(IN)  :: RBLEV
      REAL, INTENT(OUT) :: DDNOX
C
      REAL :: DDNOXX                               ! Local variables
C
C
      IF(MY.LT.1988.OR.MY.GT.2003.OR.ICY.LT.1988.OR.
     *   IROAD.EQ.4.OR.VVHDDV.EQ.0) THEN
        DDNOX = 0.0                               ! Out of Range: No defeat device
effects
        RETURN
      ELSEIF((MY.EQ.2002.OR.MY.EQ.2003).AND.IPULL.EQ.1) THEN
        DDNOX = 0.0                                ! Out of Range if no pull ahead
effects
        RETURN
      ENDIF
C
      IF(MY.GE.2004) THEN
         IMY = 1
      ELSEIF(MY.LE.1987) THEN
         IMY = 18
      ELSE
         IMY = 2004 - MY + 1
      ENDIF
C
C
      IF(IV.GE.16.OR.IV.LE.19) THEN
```

```
            IVV = 1
         ELSEIF(IV.EQ.26.OR.IV.EQ.27) THEN
            IVV = 1
         ELSEIF(IV.EQ.20.OR.IV.EQ.21) THEN
            IVV = 2
         ELSEIF(IV.EQ.22) THEN
            IVV = 3
         ELSEIF(IV.EQ.23) THEN
            IVV = 4
         ENDIF
C
         IF(IBUILD.EQ.2 .AND. (RBLEV.GT.0.AND.RBLEV.LE.0.90) ) THEN
           DDNOXX = RBLEV*((RBLD(IMY,IVV)-0.10*NEFFCT(IMY,IVV))/0.90)
     *               + (1-RBLEV)*NEFFCT(IMY,IVV)
         ELSEIF(IBUILD.EQ.2 .AND. RBLEV.GT.0.90) THEN
           DDNOXX = RBLD(IMY,IVV)
         ELSEIF(IBUILD.EQ.1 .OR. (RBLEV.LE.0.AND.IBUILD.EQ.2) ) THEN
           DDNOXX = NEFFCT(IMY,IVV)
         ELSE
           DDNOXX = RBLD(IMY,IVV)
         ENDIF
C
         IF(IROAD.EQ.1) THEN
            DDNOX = DDNOXX * FLEET(IMY,IVV) * URBAN(IMY,IVV)
         ELSEIF(IROAD.EQ.2) THEN
            DDNOX = DDNOXX * FLEET(IMY,IVV) * ARTERL(IMY,IVV)
         ELSEIF(IROAD.EQ.3) THEN
            DDNOX = DDNOXX * FLEET(IMY,IVV) * EXPRES(IMY,IVV)
         ENDIF
C
         RETURN
         END
```

```
      MODULE DDDATA
C
      IMPLICIT NONE
      SAVE
C
      INTEGER, PARAMETER :: NCY = 18
      INTEGER, PARAMETER :: NVCLS = 4
C
      REAL, DIMENSION(NCY,NVCLS) :: NEFFCT
      REAL, DIMENSION(NCY,NVCLS) :: URBAN
      REAL, DIMENSION(NCY,NVCLS) :: ARTERL
      REAL, DIMENSION(NCY,NVCLS) :: EXPRES
      REAL, DIMENSION(NCY,NVCLS) :: FLEET
      REAL, DIMENSION(NCY,NVCLS) :: RBLD
C
      INTEGER, DIMENSION(NVCLS)  :: IRBLD
C
C  Dimension 18 reflects the MY's and 4 reflects the vehicle classes.
C  In RBLD - 7 reflects the MY's and 4 reflects the vehicle classes.
C
C  Values for NEFFCT are the increase in NOx emission levels
C  as the result of the heavy-duty NOx defeat device.
C
C  Light duty includes all diesel except classes 6,7,8a and 8b.
C
C..First entry is for model year 2004.  Last entry is
C  model year 1987 and earlier.  Negatives reflect Pull ahead effects.
C  Value of Zero is assigned if no Pull Ahead or effect.  There are no
C  effects for model years 2004+ or 1987 and earlier.
C
C..URBAN is the fraction of the time that the defeat device operates
C  when an equipped vehicle is operating in Urban type driving.
C
C..ARTERL is the fraction of the time that the defeat device operates
C  when an equipped vehicle is operating in Arterial type driving.
C
C..EXPRES is the fraction of the time that the defeat device operates
C  when an equipped vehicle is operating in Expressway type driving.
C
C..FLEET is the fraction of the fleet that is equipped with a defeat
C  device.
C
C..First year is 1999+ and last is 1993 and earlier.
C  Rebuilds only in 1994 through 1998 MYs for Plan A.
C..7.00 g/bhp-hr is the rebuild emission target.
C  Rebuild effect is the difference between the value and 7.00.
C
C..IRBLD is the age of a vehicle when the first rebuild is done.
C  parameters are available for the four vehicle classes.
C  These parameters are currently implicit in the results;  thus,
C  the array IRBLD is not currently used in Defeat.
C
      DATA IRBLD / 99, 12, 5, 3 /
C
C
      DATA NEFFCT/
C  LIGHT DIESELS & BUSES
     *0.0000, -1.6300, -0.4075, 15*0.0000,
C  MEDIUM DIESELS (CLS 6 & 7)
     * 0.0000, -1.8500,-0.4625, 0.0000, 0.2420,
     * 0.3295,  3.3623, 2.7163, 2.7408,
```

```
     * 2.9136,  2.4900, 2.5700, 0.0680,
     * 0.0680,  0.7890, 1.5000, 1.5000, 0.0000,
C  8A HEAVY-DUTIES
     * 0.0000,-1.8400, -0.4600, 0.0000, 1.1031,
     * 1.4863,  8.2377, 7.1143, 6.9407,
     * 7.1260,  6.9118, 7.4985, 7.9025,
     * 8.8713,  8.3125, 8.9200, 8.9200, 0.0000,
C  8B HEAVY-DUTIES
     * 0.0000, -1.8400,-0.4600, 0.0000, 1.4488,
     * 1.9520,  8.2617, 7.2067, 6.9501,
     * 7.1022,  6.8980, 7.3978, 7.7489,
     * 8.8179,  7.8961, 8.9200, 8.9200, 0.0000/
C
      DATA RBLD/
C  LIGHT DIESELS & BUSES
     *0.0000, -1.6300, -0.4075, 15*0.0000,
C  MEDIUM DIESELS (CLS 6 & 7)
     * 0.0000, -1.8500,-0.4625, 0.0000, 0.2420,
     * 0.3295,  3.3152, 2.4226, 2.4251,
     * 2.4424,  2.4000, 2.5700, 0.0680,
     * 0.0680,  0.7890, 1.5000, 1.5000, 0.0000,
C  8A HEAVY-DUTIES
     * 0.0000,-1.8400, -0.4600, 0.0000, 1.1031,
     * 1.4863,  3.8118, 2.8624, 2.8451,
     * 2.8636,  2.8422, 7.4985, 7.9025,
     * 8.8713,  8.3125, 8.9200, 8.9200, 0.0000,
C  8B HEAVY-DUTIES
     * 0.0000, -1.8400,-0.4600, 0.0000, 1.4488,
     * 1.9520,  3.8142, 2.8717, 2.8460,
     * 2.8612,  2.8408, 7.3978, 7.7489,
     * 8.8179,  7.8961, 8.9200, 8.9200, 0.0000/
C
      DATA URBAN/
C  LIGHT DIESELS & BUSES
     * 0.0000,  1.0000,  1.0000, 15*0.0000,
C  MEDIUM DIESELS (CLS 6 & 7)
     * 0.0000,  1.0000,  1.0000, 0.0009, 0.0009,
     * 0.0009,  0.0009, 0.0042, 0.0049,
     * 0.0692,  0.1200, 0.1200, 0.0000,
     * 0.0000,  0.0000, 0.0000, 0.0000,  0.0000,
C  8A HEAVY-DUTIES
     * 0.0000,  1.0000,  1.0000, 0.0210, 0.0210,
     * 0.0210,  0.0210, 0.0083, 0.0107,
     * 0.0468,  0.0341, 0.0271, 0.0188,
     * 0.0295,  0.0612, 0.0000, 0.0000,  0.0000,
C  8B HEAVY-DUTIES
     * 0.0000,  1.0000,  1.0000, 0.0267, 0.0267,
     * 0.0267,  0.0267, 0.0116, 0.0115,
     * 0.0487,  0.0362, 0.0299, 0.0216,
     * 0.0363,  0.0753, 0.0000, 0.0000,  0.0000/
C
C
      DATA ARTERL/
C  LIGHT DIESELS & BUSES
     * 0.0000,  1.0000,  1.0000, 15*0.0000,
C  MEDIUM DIESELS (CLS 6 & 7)
     * 0.0000,  1.0000,  1.0000, 0.2000, 0.2000,
     * 0.2000,  0.2000, 0.0385, 0.0247,
     * 0.3516,  0.6100, 0.6100, 0.0000,
     * 0.0000,  0.0000, 0.0000, 0.0000,  0.0000,
C  8A HEAVY-DUTIES
```

```
     * 0.0000,  1.0000,  1.0000, 0.3651, 0.3651,
     * 0.3651,  0.3651, 0.3592, 0.3399,
     * 0.4022,  0.3704, 0.4080, 0.4392,
     * 0.5095,  0.5093, 0.6600, 0.6600,  0.0000,
C  8B HEAVY-DUTIES
     * 0.0000,  1.0000,  1.0000, 0.3949, 0.3949,
     * 0.3949,  0.3949, 0.3881, 0.3511,
     * 0.4130,  0.3825, 0.4103, 0.4384,
     * 0.5188,  0.4810, 0.6600, 0.6600,  0.0000/

      DATA EXPRES/
C  LIGHT DIESELS & BUSES
     * 0.0000,  1.0000,  1.0000, 15*0.0000,
C  MEDIUM DIESELS (CLS 6 & 7)
     * 0.0000,  1.0000,  1.0000, 0.8220, 0.8220,
     * 0.8220,  0.8220, 0.5026, 0.5396,
     * 0.9249,  0.9800, 0.9800, 0.0000,
     * 0.0000,  0.0000, 0.0000, 0.0000,  0.0000,
C  8A HEAVY-DUTIES
     * 0.0000,  1.0000,  1.0000, 0.9225, 0.9225,
     * 0.9225,  0.9225, 0.9154, 0.9153,
     * 0.9439,  0.9357, 0.9510, 0.9568,
     * 0.9023,  0.8925, 0.9800, 0.9800,  0.0000,
C  8B HEAVY-DUTIES
     * 0.0000,  1.0000,  1.0000, 0.9377, 0.9377,
     * 0.9377,  0.9377, 0.9373, 0.9285,
     * 0.9533,  0.9478, 0.9625, 0.9697,
     * 0.9064,  0.8756, 0.9800, 0.9800,  0.0000/

      DATA FLEET/
C  LIGHT DIESELS & BUSES
     * 0.0000,  1.0000,  1.0000, 15*0.0000,
C  MEDIUM DIESELS (CLS 6 & 7)
     * 0.0000,  1.0000,  1.0000, 0.0000, 1.0000,
     * 1.0000,  1.0000, 0.4950, 0.2470,
     * 0.0592,  0.0120, 0.0060, 0.0000,
     * 0.0000,  0.0000, 0.0000, 0.0000,  0.0000,
C  8A HEAVY-DUTIES
     * 0.0000,  1.0000,  1.0000, 0.0000, 0.9225,
     * 0.9225,  0.9225, 0.9154, 0.9153,
     * 0.9439,  0.9357, 0.9510, 0.9568,
     * 0.9023,  0.8925, 0.9800, 0.9800,  0.0000,
C  8B HEAVY-DUTIES
     * 0.0000,  1.0000,  1.0000, 0.0000, 1.0000,
     * 1.0000,  1.0000, 1.0000, 1.0000,
     * 1.0000,  1.0000, 1.0000, 0.9940,
     * 0.4680,  0.3400, 0.1510, 0.0880,  0.0000/
C
      END MODULE DDDATA
```