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Modeling IVHSEmission Impacts Volume II: Assessement Of The Caline 4 Line Source Dispersion Model

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Modeling IVHS Emission Impacts Volume 11: Assessment of the CALINE 4 Line Source Dispersion Model

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Modeling IVHS Emission Impacts

Volume 11:
Assessment of the CALINE 4 Line Source Dispersion Model

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Modeling IVHS Emission Impacts
Volume 11: Assessment of the CALINE 4 Line Source Dispersion Model

by:
Simon Washington
Randall Guensler
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July 28th, 1994

Abstract:

This report assesses the ability of the emission estimating algorithms contained in version 4 of the CALINE line source dispersion model developed by Caltrans (CALINE 4) to accurately predict carbon monoxide emissions from a fleet of motor vehicles. The CALINE 4 model contains algorithms that predict carbon monoxide emissions from discrete modal events of idle, cruise, acceleration, and deceleration. The vehicle test fleet used for the analyses are those vehicles contained in the Speed Correction Factor data base developed by both the United States Environmental Protection Agency and the California Air Resources Board (CARB).

A BASIC computer program was used to assess and compare the performance of the CALINE 4 algorithms to those incorporated in version 7F of the EMFAC model (EMFAC 7F) employed and developed by the CARB. The analyses demonstrate that the currently employed CALINE 4 algorithms are slightly superior to those contained in EMFAC 7F, and when modified to utilize individual emission rates (instead of fleet average emission rates), the CALINE 4 algorithms are far more robust at predicting fleet emission rates. The authors recommend that the CALINE 4 model be revised (during planned future revisions) to incorporate individual emission rates into its emission estimation procedures.

The modified CALINE 4 model algorithms are used to predict CO impacts of an applied intelligent vehicle and highway system concept; automatic vehicle identification applied to electronic tolling operations. The analyses show that electronic tolling in place of conventional toll plazas offers significant CO reductions under three different operating scenarios. The authors conclude that under certain applications, IVHS technologies *can* be beneficial to air quality.

Keywords: Emissions, Environmental Impact, Intelligent Vehicle and Highway Systems, Automatic Vehicle Identification, Electronic Toll Collection, Evaluation Models

Executive Summary:

This report presents an assessment of the 'modal' emission prediction algorithms contained in the CALINE 4 line source dispersion model. These algorithms are employed by the CALINE 4 model when the intersection modeling option is employed by the user. Assessed in this report is the ability of the CALINE 4 algorithms to adequately predict carbon monoxide emissions from light duty automobiles. The predictive abilities of the CALINE 4 algorithms are compared with the algorithms employed in EMFAC 7F, the California Air Resources Board mobile source emissions model. The algorithms are compared based on their ability to predict carbon monoxide emissions fiom vehicles in the Speed Correction Factor (SCF) data base, the most recent and comprehensive aggregate emission testing data from a variety of standard testing cycles. The data base consists of 14 speed cycles on which to evaluate the two models' algorithms. The authors also assess modifications to the CLINE 4 and EMFAC 7F models, which are shown to yield superior predictive abilities.

To simulate the internal algorithms in the CALINE 4 and EMFAC 7F models, a BASIC computer program was written, debugged, and compiled. The program simulates the predicted emission inventories for a vehicle fleet (the fleet tested on the selected speed cycle) by both model algorithms, under both conventional and modified algorithm versions of the models. The program provides the user with the flexibility to choose a number of menu options to run a variety of analyses. The outputs are saved to files which can be printed and inspected by the user. Examples of program output and the actual BASIC programming code are provided in the appendices. Also, a compiled version of the program is provided for inspection.

The assessment described is primarily statistical in nature. Statistical measures such as bias in the mean emission response, comparison of mean squared prediction error, comparison of total emission estimates, comparison of R-Square values, and comparison of Adjusted R-Square values are computed and presented.

The preliminary findings suggest that the averaging methodology currently employed in EMFAC 7F and CALINE 4 significantly reduce their ability to predict carbon monoxide emissions from individual vehicles. When average emission values are used, the vehicle to vehicle variation in CO emissions is lost, and CO emissions become systematically under or overpredicted, depending on individual vehicle emissions behavior. The advantage of the CALINE 4 algorithms compared to the EMFAC 7F algorithms in predicting CO emissions from individual vehicles is due to their inclusion of an idle factor (which is derived from EMFAC 7F or MOBILE), which provides a degree of flexibility that EMFAC 7F does not have. In addition, the CALINE 4 algorithms utilize speed-acceleration products which differ significantly from cycle to cycle. Overall, however, the 'modal' model does not perform significantly better than EMFAC 7F when all statistical measures are considered.

Furthermore, both model algorithms are extremely sensitive to assumptions about the proportion of high emitting vehicles present in the vehicle fleet. This is problematic because mis-characterization of the vehicle fleet causes systematic under or over-prediction in emission estimates, and because two vehicles can exhibit extraordinarily different emissions behavior under extreme enrichment events, causing additional bias in emission estimates.

When individual vehicle Bag 2 and Idle emission rates are used, however, we see a marked improvement in both the EMFAC 7F and CALINE 4 algorithms. This is due to their increased ability to predict the high emitting vehicles. The high r-square and adjusted r-square values suggest that the algorithms are good ones. These results are mis-leading, however, since the highemitting vehicles are extremely influential observations, and account for the majority of the explained emissions variation. In other words, the few extremely highemitters contained in the data set drown out the ability of the algorithms to explain important causes of emission differences between 'normal' emitting vehicles.

The utility of the improved CALINE 4 model algorithms are demonstrated with the assessment of an applied IVHS technology; electronic toll collection using automatic vehicle identification. The model algorithms are applied to a two alternative scenario: a link with a conventional toll plaza, and the same link with electronic toll collection. The results demonstrate that the improved CALINE 4 model algorithms can resolve emissions under two different driving scenarios involving various speed-time profiles. The algorithms predict emission differences based upon contributions from deceleration, idle, and acceleration events under the conventional toll plaza scenario. The results suggest that adequately modeling subtle changes in speed-time profiles is plausible, and that micro-simulation modeling techniques can be upgraded to meet the challenge. The results also suggest that when cleverly applied, electronic tolling operations using automatic vehicle identification technologies can signficantly reduce carbon monoxide emissions.

The implications of the findings are dependent upon the intended application of the algorithms. If the intent is to predict the overall emissions from a fleet, the algorithms may perform reasonably well (provided any bias is removed from average emission estimates). However, if the intent is to discern the emission impacts from various transportation control measures or intelligent vehicle highway system technologies, then the algorithms may not perform very well. Clearly, with current emphasis on evaluation of TCM's and other demand-side management solutions, and with emerging technological fixes such as IVHS applications lurking around the corner, we need to consider upgrading the models to properly evaluate modem alternatives.

The authors acknowledge the different intended uses of the two model algorithms being assessed in this report. The CALINE 4 model is primarily used for local carbon monoxide 'hot spot' analyses, while the EMFAC 7F model is primarily used for regional emission inventory purposes. This distinction is important when we consider the importance and impact of model algorithm deficiencies with regard to air quality analyses.

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1 Introduction:

The CALINE 4 line source dispersion model created and used by Caltrans estimates CO, NOx, and suspended particle concentrations. It uses the Guassian diffusion equation to distribute air pollution over and along modeled roadways (Benson, 1989). The model is approved by the USEPA as a tool to assess carbon monoxide hotspots, and is used primarily for local project analyses. The model contains algorithms that estimate CO emissions contributions from modal events of idle, acceleration, deceleration, and cruise (see chapter 3.0). The duration and magnitude of the events are determined by user inputs describing traffic behavior at an intersection (or intersections). For instance, the user describes an intersection by providing information such as average deceleration time, acceleration time, and free flow *speed* (Benson, 1989). When the intersection option is chosen, the CO emissions estimates that result are the cumulative total of CO emission contributions from the vehicular modal events.

The inability of the United States Environmental Protection Agency's (USEPA) MOBILE and the California Air Resource Board's (CARB) EMFAC 7F emissions models to estimate modal emissions from motor vehicles has prompted Caltrans to investigate the ability of CALM 4 to estimate CO emission under similar evaluation criteria. The main concern is that since CALINE 4 is based in part upon some of the same methodology as both EMFAC 7F and MOBILE, it will similarly predict CO emission poorly. The main connection between the operation of the regional emission models (EMFAC 7F and MOBILE) and CALINE 4 is that inputs from the regional models describing vehicular emissions behavior (FTP Bag 2 and Idle emission rates) are used as inputs to CALM 4. In addition, the algorithms in CALINE 4 are similar to those incorporated in EMFAC 7F and MOBILE in that all use some sort of ratio of emissions to 'correct' a baseline emission rate.

This research assesses the ability of the CALINE 4 model algorithms to adequately predict measured CO emission from motor vehicles tested on numerous laboratory test cycles (see chapter 4.0). As a means of comparison, the algorithms are compared against the CO emission prediction algorithms contained in the EMFAC 7F emissions model *(see* chapter 3.0). The algorithms are dissected to determine where prediction errors are likely to originate, and where the algorithms may be improved. The focus is on statistical measures of performance such as mean bias in estimates, coefficient of determination, and mean square prediction error.

To perform the analyses, a BASIC computer program is developed that provides a great deal of flexibility in analyses options *(see* chapter 2.0). The program accesses the *speed* correction factor data base and manipulates the data into a form so that both CALINE 4 and EMFAC 7F emission prediction algorithms are duplicated.

Finally, the **CALINE 4** model (with recommended modifications) is used to predict the CO emission impacts from an intelligent vehicle highway system concept - application of electronic tolling operations using automatic vehicle identification technologies (*see* chapter 5.0).

2 Description of BASIC Program Used to Assess CALINE 4:

A BASIC program entitled "MODAL" was written and compiled using Microsoft Visual BASIC for MS-DOS. The basic program first disaggregates emission testing cycles into modal (acceleration, deceleration, cruise, and idle) components based upon user-provided parameters. The program then simulates the emission algorithms within CALINE 4, EMFAC 7F, and a new modal model (UCDMODAL) to predict vehicular CO emissions. The BASIC program (MODAL) accomplishes five tasks which correspond to its main menu selections. The remainder of this section explains the menu choices and internal workings of the MODAL program. The BASIC code is provided in appendix A.

2.1 Main Menu Option I - "Receive Detailed Description of Program Capabilities"

The main menu selection # 1 provides a brief description of the program and its functions. It is primarily there to remind users as to the differences between the different types of output provided by the program. This menu can be bypassed to access the program report creating modules.

2.2 Main Menu Option 2 - "Break Down a Test Cycle into Sequential Steady-State Modes"

The program's main menu selection # 2 allows the user to select a test cycle to break down into modal events. Modal events are output in the order that the modal events occurred in the parent cycle...this allows the user to compare mode occurrences to the speed-time trace of the parent cycle. This menu selection provides no emission information.

The test cycles currently coded in second-by-second format and supported by MODAL are those cycles used to collect the SCF data (summarized in table 1). Additional test cycles will be supported in the next version of the model. The table also shows some of the pertinent characteristics unique to each of the cycles. The age of the vehicles tested on these cycles ranged from 1977 model years to 1990 model years.

Whichever test cycle is chosen by the user, the MODAL program breaks down the test cycle into steady-state discrete modal events. These results are written to hard disk as report1.out and contain a sequential listing of all steady-state modes contained in the test cycle. An example of output from this program feature is provided in appendix B.

The way in which the MODAL program breaks down test cycles into discrete steady-state modal events depends upon the user-selected cut-rate. The cut-rate is defined as the instantaneous acceleration rate used to distinguish between modal events. For example, if a vehicle is traveling along at a steady cruise, a cut-rate of 0.80 kph/sec

Table 1: Summary Information on Test Cycles Used in Analyses

Cycle Name	Number of Vehicles Tested	Source of Test Cycle	Length of Cycle in Seconds	Average Speed of Cycle in KPH
Federal Test Procedure - Bag 1	464	USEPA	505	41.20
Federal Test Procedure - Bag 2	464	USEPA	866	25.81
Federal Test Procedure - Bag 3	464	USEPA	505	41.20
Highway Fuel Economy Test	464	USEPA	765	77.69
High Speed Test Cycle # 1	25	CARB	474	72.54
High Speed Test Cycle # 2	25	CARB	480	82.13
High Speed Test Cycle # 3	69	CARB	486	92.96
High Speed Test Cycle # 4	69	CARB	492	103.71
Low Speed Test Cycle #1	236	CARB	624	6.47
Low Speed Test Cycle #2	236	CARB	637	5.86
Low Speed Test Cycle #3	236	CARB	616	3.94
New York City Cycle	464	USEPA	598	11.43
Speed Correction Factor Cycle 12	464	USEPA	349	19.43
Speed Correction Factor Cycle 36	464	USEPA	996	57.70

means that if the vehicle accelerates at greater *than* 0.80 kph/sec the beginning of an acceleration event is identified. Once the acceleration rate drops below 0.80 kph/sec, the end of the acceleration event and the beginning of the next cruise event is defined. The same concept carries over to the deceleration events, only the sign of the cut-rate is changed to reflect decelerations.

Figures 1 and 2 illustrate how the selected cut-rate affects the breakdown of a cycle into steady-state modes quite eloquently. In the figures the y-axis is *speed* in kph, while the x-axis is time increments. Figure 1 shows a speed-time profile for a hypothetical test cycle with a cut-rate of 0.80 kph/sec, while Figure 2 shows the same speed-time profile with a cut-rate of 1.61 kph/sec. In both figures, the first event is a cruise, followed by an acceleration, another cruise, a deceleration, and finally a cruise event.

The figures show that the length of modal events is significantly affected when the cut-rate is changed. With cut-rates around 1.00 kph/sec, the relative length of accelerations and decelerations are shortened, while the length of cruise events are lengthened. In contrast, with cut-rates around 0.5 kph/sec or smaller, the relative length of acceleration and deceleration events are longer, while cruise events are shorter.

The implications of the variation in cut-rates is important. For example, in the internal algorithms contained in CALINE 4, modal CO emissions are proportional to the amount of time spent in any particular mode of vehicle operation. For example, accelerations are calculated on time rate based upon the number of seconds in

Figure 1: Sped-Time Trace for Hypothetical Vehicle 0.5 kph/sec Cut-rate

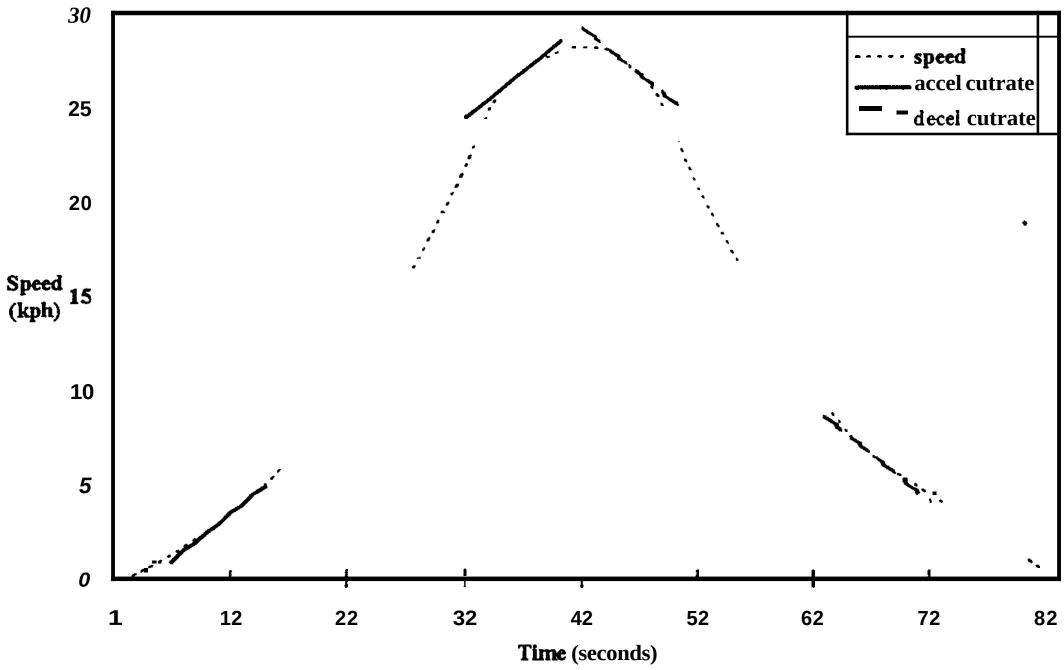
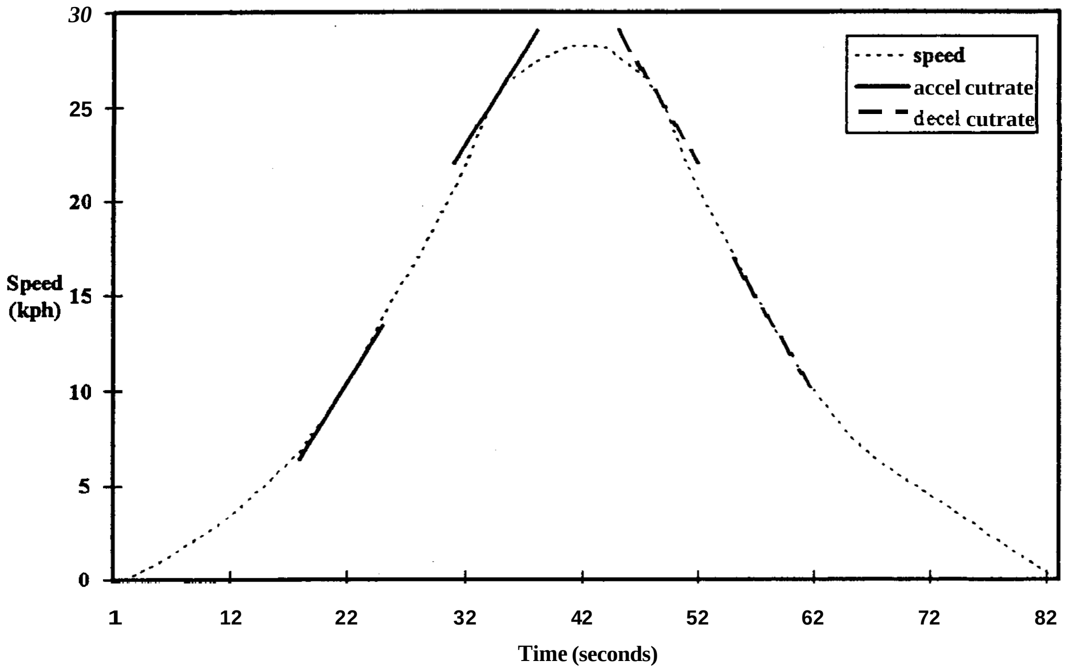


Figure 2: Speed-Time Trace for Hypothetical Vehicle 1.0 kph/sec Cut-rate



acceleration. If a large cut-rate is chosen, the time in acceleration is relatively short, resulting in lesser contribution from acceleration generated CO emissions. The same holds true for CO emissions generated from other modes. The sensitivity of emission estimates to cut-rate are explored in the analyses.

2.3 Main Menu Option 3 - "Single Vehicle Summary Table Showing Emission Estimates by Mode"

This menu option takes the information obtained from #2 above and presents it along with emission estimates by all models for a single vehicle on a single cycle. Instead of being provided in a sequential manner, the results are tabulated according to mode, i.e. acceleration events...., deceleration events...., etc. The results are saved to a file named report2.out and can be printed after a program run.

Menu option #2 will prompt the user for input regarding attributes of an individual vehicle. These inputs include the FTP-Bag 2 emission rate in grams/mile, the idle emission factor in grams/hour, the gram/mile result for the chosen test cycle (i.e. Highway Fuel Economy Test), and the cut-rate for the analysis (see menu option # 2 discussion). The user also has the option to choose between using individual vehicle Bag 2 and Idle emission rates or the test fleet average values. Selecting individual emission rates allows the models to predict between vehicle emission rate differences, while selecting fleet average emission rates constrains the EMFAC 7F and CALINE 4 models to only predict average CO emissions for the fleet. Since average emission values are used in the actual models, this menu option replicates the true model outputs. Selecting individual vehicle emission inputs, however, shows how the model functional forms operate using real values for the fleet's vehicles. In addition, individual vehicle results provide information on whether the model provides additional explanatory power relative to the other models.

Report2.out also contains summary information about CO emissions estimates from the CALINE 4, EMFAC 7F, and UCDMODAL models. This information includes total emission estimates, mean emission estimates, and differences in means. The estimates from the models are always compared to actual emission measurements.

In addition, a prediction factor is calculated that shows the ratio of CALINE 4, EMFAC 7F, and UCDMODAL estimates to actual CO emissions. This can be used as a general measure of prediction bias for the models on any particular vehicle. An example of this report is found in appendix C.

2.4 Main Menu Option # 4 - "Emission Results for All Vehicles Tested on a Cycle"

This menu option summarizes the results provided in report2.out in tabular format. The emission estimates by all models and for each vehicle test are provided. The only input needed is the cut-rate for the run and selection of individual or average fleet emission rates. This run can take up to 5 minutes for 464 vehicles (e.g. FTP-Bag 2) on a IBM 486-33 computer. A visual prompt illustrates your computers' progress in this menu choice.

In addition to emission summaries cognate to those provided by menu # 3, approximated Analysis of Variance (ANOVA) results are provided (see Model Performance Comparisons for Description of approximated ANOVA results). These statistics include sum of squares for model specifications, for model errors, and for model totals. R-Square Adjusted values are provided as a means of comparing model performance. Again, all comparisons are made between model emission estimates and actual CO emissions measured on the test cycle.

In addition to Report3.out, this menu option writes to a file named residual.out, which contains the actual CO emissions on a cycle, the CALINE 4 residual, and the EMFAC 7F residual per record. All of the vehicles that were tested on the user-selected cycle comprise the records in the residual.out file. An example of Report3.out can be found in appendix D.

2.5 Main Menu Option # 5 - "Model Performance Results for All Vehicles on all Cycles"

This menu option compiles the summary statistics for menu option #4 runs on all of the cycles at 0.2 cut-rate increments from 0.032 kph/sec to 1.61 kph/sec. It is only available in the full-blown version of the program. Essentially, this run only needs to be done once to obtain the summary information, as menu option #4 and #3 provide much more detail and insight as to model performance. This run should be used with caution, as it takes over 5 hours on an IBM 486-33 personal computer. Your progress is displayed as the computer works through these algorithms.

A printout of this menu option is provided in the appendix E, and is also contained in various tables throughout the text, so it should not be necessary to use this option (The compiled version of MODAL currently has only menu options 1 through 4).

2.6 Some Further Comments about UCDMODAL

2.6.1 Installing and Running MODAL

MODAL should be installed by first creating a directory in the C drive named MODAL. Then, copy the contents of the provided floppy disk into the directory. Then, to invoke the MODAL program, change to the MODAL directory. then type MODAL. Prompts will then direct the user through the various menus and options.

2.6.2 File Management

After you run MODAL, a screen prompt will indicate the name and location of the file that was generated by the program. If you run the same menu option in MODAL again you will write over the file you just created, as the subsequent run assigns the same filename to the output. In order to avoid losing files, print out the files after each run, or rename files so you can retrieve them at a later time.

2.6.3 Interpreting Basic Code

The Basic Code contained in the appendix **A is** documented so that people can investigate how model algorithms are simulated. The program is structured in the following order: Program Title and Identification; Definition of Variables and Arrays; User Input Menus and Prompts; File Management; Program execution; Model Simulation Subroutines; and Report Printing Subroutines. All modules of the program include remark statements which convey the purpose of the basic code.

3 Theoretical Basis of Alternative Models:

This section provides a description of the theoretical and empirical bases for alternative model development. All models assessed in this research effort are discussed. Emphasis is given to topics relevant to the validation of the models, and the reader is directed to a more complete discussion of individual model development when appropriate.

3.1 CALINE 4:

The CALINE 4 line source dispersion model has been developed over many years by the California Department of Transportation (Caltrans). It has gone through 3 revisions since the original version in 1972. It is a fairly complex model that uses the guassian dispersion equation to distribute estimated emissions along a roadway. When the intersection link option is employed, CO emissions are estimated on a modal basis, that is, equations or algorithms are developed to predict CO emissions from the modal events idle, cruise, acceleration, and deceleration. Of course, the focus of this research effort is on CO emissions predicted by CALINE 4.

The latest version of the algorithms employed in the CALINE 4 model are similar to those in the Colorado Department of Highways (CDOH) model released in 1980. The data used to estimate the CDOH models were derived from 37 discrete modes driven by 1020 lightduty vehicles ranging from 1957 model year to 1971 model year. A subset of 62 vehicles was used to estimate the coefficients employed in the CALINE 4 algorithms (Benson, 1989). In both the Caltrans and CDOH model development efforts, a strong relation was noted between the modal emissions to FTP-75 emissions ratio and the average acceleration speed product (AS) for the particular acceleration mode. Consequently, AS is one of the explanatory variables used in the CALINE 4 model. For a more detailed description of the CALINE 4 model, refer to Benson, 1989.

The CALINE 4 model is empirical and not deterministic. This means that the model is estimated using observed emissions and vehicle behavior, rather than using more causal variables such as fuel volatility, cylinder size, mechanical efficiency losses, etc. The advantage of such a model is that it is easy to measure the inputs, speed and acceleration. The disadvantage, however, is that we must not misinterpret the results to be universal, or to be transferable across time.

The CALINE 4 model can be written as:

$$TE_{ik} = EI_{ik} + EA_{ik} + EC_{ik} + ED_{ik}$$

where;

TE_{ik} = Total CO emission estimate for vehicle i on cycle k in grams,

EI_{ik} = CO emissions from idle events for vehicle i on cycle k in grams,

EA_{ik} = CO emissions from acceleration events for vehicle i on cycle k in grams,

EC_{ik} = CO emissions from *cruise* events for vehicle i on cycle k in grams,

ED_{ik} = CO emissions from deceleration events for vehicle i on cycle k in grams.

The emission contributions from modal events are defined as:

$$EI_{ik} = (IR_{[grams/sec]}) * (t_{i[secs]}),$$

where,

IR is measured idle emission rate,

t_i is time in the idle operating mode.

$$EA_{ik} = [(FTPB2_{[grams/min]}) * (C1) * EXP\ (C2 * AS)] * t_{a\ [secs]} * 1_{[min]}/60_{[sec]},$$

where;

FTPB2 is measured emission rate on FTP Bag2,

Coefficients C1 = 0.75 and C2 = 0.0454 for acceleration condition 1,

Coefficients C1 = 0.027 and C2 = 0.098 for acceleration condition 2,

AS is the acceleration *speed* product based upon average *speed* and average acceleration rate *of* the accel mode,

Acceleration condition 1 is for vehicles *starting* at rest and accelerating up to 72.42 kph,

Acceleration condition 2 is for vehicles *starting* at 24.14 kph *or* greater and accelerating up to 96.56 kph,

t_a is the time in the acceleration mode.

$$EC_{ik} = (FTPB2_{[grams/min]})) * [(0.494 + 0.000227 * S*1.6094_{[kph]})\ ^{2})] * (t_{c\ [secs]} * 1_{[min]}/60_{[sec]},$$

where;

FTPB2 is measured emission rate on FTP Bag2,

t_c is the time in the *cruise.* event,

S is the average *speed* of the vehicle *in* the modal event in kph.

$$ED_{ik} = (IR_{[grams/sec]}) * (t_{d[secs]})*1.5,$$

where,

IR is measured idle emission rate,

t_i is time in the deceleration operating mode.

The CALINE 4 algorithms *can* be used to sum CO emissions from steady-state modal events for a vehicle on any cycle. For example, a given speed-time trace *can* be parsed into discrete model events of idle, cruise, acceleration, and deceleration. The CO emissions from these events *can* be summed over the cycle to obtain the total emission estimate.

It should be noted that the FTP Bag **2** emission rate and the IDLE emission rate used in the CLINE **4** program is an estimated average value for the fleet. Of course, the **real** average values **for** the fleet being simulated are not really **known,** so estimates are used. It is **shown** later that **by** using individual FTP Bag **2** and IDLE emission rates, model performance is improved significantly.

The non-linear regression form of the CLINE **4** algorithms *can* be written **as:**

$$TE_{ik} = C1_{ik} + D1_{ik}*[\beta 1*EXP(\beta 2 * AS)] + D2_{ik}*[\beta 3*EXP(\beta 4*AS)] + C2_{ik}*\beta 5 + \beta 6*S + Error;$$

where;

TE_{ik} = Total CO **emission** estimate for vehicle i on cycle k in grams,

$C1$ = constant *term* including idle and deceleration ***CO*** emissions,

$C2$ = constant term consisting of **BAG 2** emission rate,

$D1$ = instrumental variable for acceleration mode type, **where**

D1 = 1 for vehicles ***starting*** at **rest,** accelerating to **72.42** kph, and

D1 = 0 for vehicles **starting at 24.14 kph** or greater and accelerating up to **96.56 kph,**

$D2$ = **instrumental** variable for acceleration mode type, where

D2 = 0 for vehicles ***starting*** at **rest,** accelerating to **72.42 kph,** and

D2 = 1 for vehicles ***starting*** at **24.14 kph** or **greater,** accelerating up to **96.56 kph,**

AS = average acceleration-speed product for acceleration mode

S = average *speed* for *cruise* event

$\beta 1 - \beta 5$ = **ordinary** least squares estimated parameters

Error = disturbance term

The regression equation is non-linear due to the non-linearity **of** the first order conditions. The parameters in the model can be estimated using ordinary least squares methods, and ***they*** are efficient estimators provided they result in normally distributed disturbances. However, since the original **data** set used to estimate the model is **as** yet unavailable, there is **not** way to tell if the disturbance terms are normally distributed.

Note that there are six estimated parameters in the CALINE **4 algorithms, as** opposed to the sixteen parameters estimated in EMFAC 7F. All other quantities in the CALINE **4** algorithms are measured quantities, such **as** the BAG **2** and Idle emission rates. It is not clear whether the constant term **(1.5)** in the deceleration **portion** of the equation was estimated with statistical methods, **or** whether it was **an** assigned quantity. In the equation above it is assumed to be an a-priori constant.

3.2 UPDATE TO CALINE 4:

A draft report by Caltrans (Wood, Nguyen, 1993), has proposed changes to the CALINE 4 model emission algorithms so a wider range of acceleration rates can be modeled. As the report is in the draft stages, it is too early to be assessed for timely inclusion into this report. It is also unclear weather this modification will be proposed as a permanent modification to the CALINE 4 model algorithms. Several comments are noteworthy however. The acceleration speed product employed in the original CALINE 4 model algorithms are replaced with a term which includes load and mass. The load term includes two components: the power required to overcome friction, and the power required to overcome inertia. The mass of vehicles is also used in the new non linear term. These additional terms are likely to offer additional explanatory power to the modal emission algorithms. Since power and mass are no doubt critical in the determination of vehicular emissions, they will likely result in an improvement to the current algorithms. The potential improvement, however, may be diminished if fleet average power and masses are used instead of individual values. The use of averages will be discussed later in the report.

3.3 EMFAC 7F:

The EMFAC 7F model developed by the California Air Resources Board (CARB) is an emissions model that operates differently than CALINE 4. Instead of taking a modal approach, EMFAC 7F uses average speed and fuel delivery technology as the two explanatory variables in the model. Based upon the attributes of these two variables, EMFAC 7F predicts a modal emission to Bag 2 emission ratio, similar to that of CALINE 4. The resultant ratio is called a speed-correction factor (SCF), and is used to estimate emissions at speeds other than 25.75 kph (at 25.75 kph measured emissions are predicted). For a complete description and analyses of the recent EMFAC 7F model, refer to Guensler, 1993.

The regression form of the EMFAC 7F model for prediction of carbon monoxide emissions is given by:

$$TE_{mn} = \{BAG\ 2_n * [EXP\ (B1_n{*}SADJ1) + (B2_n{*}SADJ2) + (B3_n{*}SADJ3) + (B4_n{*}SADJ4)]\} + error,$$

where;

TE_{mn} = Total CO emissions for vehicle m from technology group n,
$BAG2_n$ = Average measured BAG 2 result for technology group n vehicles,
$SADJ1$ = (16 - average prediction speed),
$SADJ2$ = (16 - average prediction speed)^2,
$SADJ3$ = (16 - average prediction speed)^3,
$SADJ4$ = (16 - average prediction speed)^4,
$B1_n - B4n$ = least squares estimated coefficients, and
$error$ = the disturbance term.

It should be noted that in the EMFAC 7F model form, 4 models are estimated based on *CARB* defined technology groups. The technology groups are dependent upon model year of the vehicle and fuel delivery technology, as given in table 2.

Also, similar to CALINE 4, EMFAC 7F uses average FTP Bag 2 emission values for the simulated vehicle fleet. Again, as is shown later, using individual Bag 2 values significantly improves the performance of the EMFAC 7F model.

CARB's model has been criticized for statistical and theoretical reasons. Among the statistical criticisms are non-normal errors, high multicollinearity among the explanatory variables, and biased parameters. The theoretical criticisms are primarily concerned with non inclusions of 'causal' explanatory variables, non-representative sample vehicle fleet of real fleet, and non-representativeness of driving cycles as compared to real driving behavior. For a more detailed description of these criticisms, consult Guensler 1993.

Table 2: Technology Groups Employed in the EMFAC 7F SCF Model

CARB Technology Group	Model Year	Fuel Delivery Technology
1	1985 or earlier	Carbureted and Throttle Body Injection
2	1985 or earlier	Port Fuel Injection
3	1986 or later	Carbureted and Throttle Body Injection
4	1986 or later	Port Fuel Injection

Similar to CALINE 4, EMFAC 7F was developed using empirical data, and is a descriptive model. It has been shown to have wide confidence and prediction intervals around the SCF curves (Guensler 1993), indicating that the model lacks important explanatory variables needed to explain a significant portion of the variation.

4 Model Performance Evaluation:

This section provides detailed discussions of comparisons between alternative model specifications. It is worth noting that both the CALINE 4 and EMFAC 7F model algorithms operate using fleet average Bag 2 and Idle rates (the CALINE 4 user inputs values derived from EMFAC 7F or MOBILE). The individual BAG 2 and Idle rates used in the following analyses represent a significant change to the way in which the model algorithms are employed, and are performed for research purposes. It will be shown that use of individual vehicle Bag 2 (and Idle) rates instead of fleet average Bag 2 rates results in superior algorithm performance. It will also prove useful to compare the effect on statistical robustness of using an averaging process as compared to retaining individual vehicle characteristics.

In the following analyses, the ability of model algorithms to predict actual emission results from 'bag' tests is used as the performance measuring stick, while statistical measures such as bias (comparison of means), mean squared prediction error, coefficient of determination, and adjusted coefficient of determination are used to compare model specifications. Before these comparisons are made, a discussion of the underlying statistical methodology is provided. In addition, selected residual plots are provided to demonstrate some characteristics of the different models. Before these comparisons are made, a discussion of the underlying statistical methodology is provided.

4.1 Statistical Methodology Employed to Compare Predictive Models

The main concern and focus of this research is to be able to predict measured emissions from a *standardized* and large data set, preferable a data set that is different than one used to estimate a model. This results in essentially a model validation process, in this particular instance, validation of the algorithms employed in the CALINE 4 line source dispersion model. By using the SCF data base as a validation data set, we *can* also compare the performance of the model to EMFAC 7F (and MOBILE) without too much difficulty. Keep in mind that EMFAC 7F and MOBILE are expected to perform better than CLINE 4, since both of these models' emission algorithms were estimated using the *speed* correction factor (SCF) data set, while the CALINE 4 model algorithms were estimated on a much older data set.

By assessing the ability of CALINE 4 algorithms to predict emissions from specific cycles in the SCF data base, we can begin to look at the effect of cycle characteristics (i.e. low-speed cycle vs. high-speed cycle) on the ability to predict emissions. For example, we *can* compare low *speed* cycle characteristics to high-speed cycle characteristics in terms of being predictable by emission algorithms.

Statistical measures are used to measure the performance of both the CALINE 4 and EMFAC 7F emission algorithms. The measures include mean prediction bias, coefficient of determination, adjusted coefficient of determination, and mean squared prediction error. Qualitative assessment of the models (covered in discussion section) includes ease of use, agreement with emission production theory, and flexibility.

Robust emission prediction algorithms possess several properties. **First,** they will not be biased in their prediction of CO emissions. Bias *can* be defined as a systematic trend or consistent under-prediction or over-prediction of emissions. One indicator of bias in model validation is the difference in means. Ideally, we want the mean value of the predicted emissions to be the same as the mean value of actual emissions. A great discrepancy in means over a large sample suggests that the model is consistently over or under predicting the actual emissions, and that the model is biased.

A second measure of predictive ability is to compare total emission predictions for a subset of the data... all vehicles on a test cycle for example. Ideally we want a statistical model to predict the total amount of emissions from a fleet accurately. This is especially important when considering emission inventories, since we want an accurate account of the emission impacts of proposed changes to operating characteristics to a fleet of vehicles. The ability to correctly predict total emissions is closely correlated to predicting mean emissions.

Closely related to the ability to adequately predict total emissions from a fleet, is the need to have a representative sample fleet in which to estimate a model. This, unlike some of the remaining desirable model properties, requires careful research design before data collection begins. To illustrate this point, consider the following scenario. **Most** of the vehicles included in the ***speed*** correction factor data base were procured through volunteering of vehicle owners. This procurement procedure, while providing a somewhat random sampling of vehicles for testing purposes, may be biased towards clean vehicles. It is conceivable that people who have tampered with their emissions control equipment would not want to offer their vehicle for emission testing purposes, Similarly, there may be other potential biases from a self-selected sample, such as economic status, geographic location, or sex. Once a sample of vehicles has been selected, it is difficult to determine (without collecting further data to verify) weather the data represents a true cross section of the vehicles in a particular region. In addition, as the test fleet becomes older, the likelihood of a mis-representative fleet becomes more and more probable. The effect of assumptions about the make-up of the vehicle fleet is explored in these analyses. We do not, however, attempt to verify weather the *speed* correction factor data set is representative of a sample vehicle fleet.

A measure of a model's ability to explain inherent variation between vehicle types is the mean squared prediction error. Essentially, the average squared difference between the predicted emission value and the actual emission for a subset of vehicles is determined, The smaller the 'mean squared prediction error' the better the model. The mean squared prediction error is often used during model validation, where the model is used to predict observations from a new data set.

Becoming increasingly important is a model's ability to explain the total variation in emission rates based on vehicle or cycle characteristics. A model that can 'capture' or explain the large variations in emissions is superior to one that cannot. It is worth noting that the current debate surrounding emissions models suggests that insufficient explanatory variables are included in models to explain much of the variation. The most commonly used measure to gauge a model's explanatory ability, the coefficient of determination, or r-square value, captures the ratio of model explained variation to total variation. This measure can be misleading however, since it does not reflect differences between variable requirements in compared models. For example, if two models have identical r-square values, we will in general select the model with fewer explanatory variables as the superior model, since it is requires fewer variables to convey the same information. Essentially, adding an independent variable to a model (coefficients), by nature of mathematics, has a higher chance of explaining more of the variation than before the variable was included. Therefore, a comparison of r-square values doesn't provide an objective means of comparison. To compensate for differences in the number of parameters in a model specification, an adjusted r-square value is used which objectifies the comparison. This new measure, which compensates by dividing the sum of squared errors and total sum of squares by their appropriate degrees of freedom, is superior to the r-square comparison measure when comparing model's with different numbers of explanatory variables.

The following sections assess the results of the tested models. In each of the analyses, assessment is done using both disaggregated data (individual vehicles) and the aggregated data (fleet averages). Please recall that the disaggregated approach is not currently employed in the model algorithms, while the aggregated results represent the true algorithms employed in the CALINE 4 and EMFAC 7F models. First, model bias is assessed, followed by an analysis of the mean squared prediction error, and finally the r-square and adjusted r-square values are provided. Then, residual plots are presented for the models. Finally an assessment of the influence of the high-emitters on model performance is presented. In each section, the statistical tools used to compare models are discussed.

4.2 Comparison of Mean Predicted Emissions

By comparing mean predicted emissions to mean observed emissions for a sub-sample of vehicles, the bias present in a model is quantified. An important thing to remember is that significant bias can exist in a model that has large explanatory power, or conversely, little bias can exist in a model with very little explanatory power. If two models have equal explanatory power, then the model with the least prediction bias would be superior to a competing model with greater bias. Similarly, if two models have equal bias, then the model with greater explanatory power would be superior.

To quantify biases in the model's emission estimates, estimated emissions were summed over a test cycle, and then averaged according to the number of vehicles in the test cycle. For example, the predicted emission estimates for vehicles tested on Bag 3 of the Federal Test Procedure are summed and then divided by 464 vehicles to compute the average emission estimate. This average emission estimate is then compared to the average observed emission result for the vehicles tested on that cycle. If there is little model bias, then the predicted and observed averages should be very close. If there is significant bias, then we expect there to be a large discrepancy between predicted and observed averages. Tables 3 and 4 show the average predicted emission values according by test for both dis-aggregated and aggregated emission data.

The tables show the mean emission estimates for CALINE 4 and EMFAC 7F for all test cycles. In these analyses, the Sample of vehicles is assumed to be all vehicles tested on a single test cycle. Of course, there are other

Table 3: Summary of Mean Carbon Monoxide Estimates on All Cycles: Individual Vehicle Bag 2 and Idle Data

Cycle Name	Number of Vehicles Tested	Mean Actual CO (grams)	Mean CO Estimate for CALINE 4 (grams) [1]	Mean CO Estimate for EMFAC 7F (grams)	Mean Bias in CO Estimate CALINE 4 (grams)	EMFAC 7F (grams)
FTP - Bag 1[3]	**464**	**73.74**	**46.03**	**32.25**	**-27.7 [2]**	**-41.5**
FTP - Bag 2	464	42.63	42.48	42.63	-0.15	0.0 [2]
FTP - Bag 3[4]	464	34.15	46.03	32.25	11.9	-1.9 [2]
Highway Fuel Economy Test	464	51.40	45.22	48.12	-6.2	-3.3 [2]
High Speed Test Cycle # 1	25	4.24	6.64	8.15	2.4 [2]	3.9
High Speed Test Cycle # 2	25	4.55	8.44	9.98	3.9 [2]	5.4
High Speed Test Cycle # 3	69	11.60	9.2 1	13.81	-2.4	2.2 [2]
High Speed Test Cycle # 4	69	38.26	12.95	50.35	-25.3	12.1 [2]
Low Speed Test Cycle #1	236	24.99	15.49	21.84	-9.5	-3.2 [2]
Low Speed Test Cycle #2	236	24.47	14.71	21.93	-9.8	-2.5 [2]
Low Speed Test Cycle #3	236	22.34	13.70	19.03	-8.6	-3.3 [2]
New York C i Cycle	464	29.20	28.28	29.52	-0.9	**0.3 [2]**
Speed Correction Factor 12	464	16.65	16.62	16.31	0.0 [2]	**4.3**
Speed Conation Factor 36	464	63.68	65.96	68.25	2.3 [2]	4.6

Based upon analyses with cut-rate = 0.97 kph/sec

[2] Smallest absolute mean bias in emission estimate

[3] Contains contributions from cold-starts

[4] Contains contributions from hot-starts

Table 4: Summary of Mean Carbon Monoxide Estimates on All Cycles: Average Bag 2 and Idle Data

Cycle Name	Number of Vehicles Tested	Mean Actual CO (grams)	Mean CO Estimate for CALINE 4 (grams)[1]	Mean CO Estimate for EMFAC 7F (grams)	Mean Bias in CO Estimate	
					CALINE 4 (grams)	EMFAC 7F (grams)
FTP - Bag 1[3]	**464**	**73.74**	**45.42**	**31.29**	**-28.3 [2]**	**-42.4**
FTP - Bag 2	464	42.63	42.59	42.64	0.0	0.0
FTP - Bag 3[4]	464	34.15	45.42	31.29	11.3	-2.8'
Highway Fuel Economy Test	464	51.40	45.24	48.55	-6.2	-2.9 [2]
High Speed Test Cycle # 1	25	4.24	6.65	8.20	2.4 [2]	4.0
High Speed Test Cycle # 2	25	4.55	8.52	9.94	4.0 [2]	5.4
High Speed Test Cycle # 3	69	11.60	9.26	13.87	-2.3	2.3
High Speed Test Cycle # 4	69	38.26	13.00	51.95	-25.3	13.7 [2]
Low Speed Test Cycle #1	236	24.99	15.13	21.95	-9.9	-3.0 [2]
Low Speed Test Cycle #2	236	24.47	14.19	22.04	-10.3	-2.4 [2]
Low Speed Test Cycle #3	236	22.34	13.58	19.13	-8.8	-3.2 [2]
New York City Cycle	464	29.20	27.20	29.25	-2.0	0.8 [2]
Speed Correction Factor 12	464	16.65	16.64	16.43	0.0 [2]	-0.2
Speed Correction Factor 36	464	63.68	66.71	66.12	3.0	2.4 [2]

Based upon analyses with cut-rate = 0.96 kph/sec

[2] Smallest absolute mean bias in emission estimate

[3] Contains contributions from cold-starts

[4] Contains contributions from hot-starts

techniques available in which to determine subsets of vehicles, but those are not explored here. In addition, using cycle tests as sample subsets allows inspection of the effect of test cycle on emission estimates.

We see from table 3 that EMFAC 7F has smaller mean bias on 8 of the test cycles, while CALINE 4 has smaller bias on 4 cycles (we exclude FTP Bag 1 and 3, since they contain contributions form cold and hot starts). Both CALINE 4 and EMFAC 7F underpredict carbon monoxide on all of the low speed cycles. CALINE 4 underpredicts on the highest 2 high-speed cycles and overpredicts on the 2 lowest high-speed cycles. EMFAC 7F tends to overpredict on all high-speed cycles. The important thing to note here is that cycle characteristics do play a role in weather carbon monoxide emissions are being adequately predicted or not.

Table 4 shows how the model algorithms work in practice (with averaged input data). We see here that EMFAC 7F again outperforms CALINE 4 in that 7 cycles exhibit less prediction bias, 3 cycles exhibit greater prediction bias, and 1 cycles is about equal (again Bag 1 and Bag 3 are not included). We see the same trends with regard to high-speed and low-speed test cycles as was demonstrated with disaggregate data. The effect exhibited here is due to difference in characteristics between the Bag 2 cycles and the test cycle. For example, there are more enrichment events in the Bag 2 cycle than in the low-speed cycles, therefore, when the ratio of Bag 2 emission to low-speed cycle carbon monoxide emissions are computed (as is done in both CALINE 4 and EMFAC 7F), we tend to underestimate the enrichment activity in the low *speed* cycles. **This** is essentially the root of the emission ratio methodology problem employed in the current models.

4.3 Mean Squared Prediction Error

One measure that has been proposed to compare the ability of models to predict a new data set is the mean square prediction error (Neter, et. al., 1990). This measure provides an objective way in which to compare several different models ability to adequately predict observations from a new or different data set. It does not however, provide an absolute measure of a model's ability to predict a new data set (see r-square later). The formula for mean square prediction error is given by:

$$MSPE = \frac{\sum_n \left(e_{pred} - e_{obs}\right)^2}{n}; \quad \text{where}$$

$MSPE$ = mean squared prediction error,

n = number of observations

e_{pred} = total *grams* **of** carbon monoxide emission estimate generated by model, and

e_{obs} = total grams of carbon monoxide observed emission value.

The results **of** the mean squared prediction error analyses are presented in tables *5* and *6* respectively for disaggregate and aggregate data. We see that when dissaggregate data is used, the CALINE 4 model exhibits lower mean square prediction error on 10 out **of** 12 of the test cycles (Bag I and Bag 3 omitted). When we **look** at the aggregate data however, we see that **EMFAC 7F** has lower mean squared prediction error on **8** out **of** 11 of the test cycles (Bag 2 test results are equivalent).

These findings *suggest* that when used with individual bag 2 and idle test results, **CALINE 4** has much greater ability to predict outlying observations than does the **EMFAC 7F** model. This *can* be explained by the fact that **CLINE 4** model algorithms contain both Bag 2 and Idle emission rates, which when combined result in a robust and flexible formulation. For example, low *speed* cycle **CO** emission characteristics might be better reflected in a vehicle's idle rate, whereas high-speed cycle CO emission characteristics are better reflected in the FTP Bag 2 rate. Once Bag 2 and Idle rates are averaged for a vehicle fleet, the **CALINE 4** algorithms lose considerable flexibility and are constrained to predict one emission estimate for any vehicle on a given cycle, whereas the **EMFAC** 7F algorithms still get variation from the **4** technology group classifications and their respective curves.

Table 5: Summary of Mean Square Prediction Error for All Cycles: Individual Vehicle Bag 2 and Idle Data

Cycle Name	Number of Vehicles Tested (n)	Mean Square Prediction Error for CALINE 4 (grams^2)	Mean Square Prediction Error for EMFAC 7F (grams^2)
Federal Test Procedure - Bag 1	464	6053	5326[1]
Federal Test Procedure - Bag 2	464	1519	0[1]
Federal Test Procedure - Bag 3	464	3785	1287[1]
Highway Fuel Economy Test	464	14676	11507[1]
High Speed Test Cycle # 1	25	35[1]	67
High Speed Test Cycle # 2	25	74[1]	122
High Speed Test Cycle # 3	69	189[1]	260
High Speed Test Cycle # 4	69	6036[1]	7885
Low Speed Test Cycle # 1	236	1842[1]	4047
Low Speed Test Cycle # 2	236	1855[1]	4107
Low Speed Test Cycle # 3	236	1830[1]	4040
New York City Cycle	464	884[1]	1651
Speed Correction Factor 12	464	360[1]	379
Speed Correction Factor 36	464	12315[1]	13298
Full model Estimate[2]	3216	4833	4943

Lowest mean square prediction error on test cycle

[2] Full model estimate based on all cycles minus Bag1 and Bag3

Table 6: Summary of Mean Square Prediction Error for All Cycles: Aggregated Vehicle Bag 2 and Idle Data

Cycle Name	Number of Vehicles Tested (n)	Mean Square Prediction Error for CALINE 4 (grams^2)	Mean Square Prediction Error for EMFAC 7F (grams^2)
Federal Test Procedure - Bag 1	464	11966[1]	12817
Federal Test Procedure - Bag 2	464	15439	15439
Federal Test Procedure - Bag 3	464	6051	5893[1]
Highway Fuel Economy Test	464	37374	37270[1]
High Speed Test Cycle # 1	25	17[1]	27
High Speed Test Cycle # 2	25	28[1]	41
High Speed Test Cycle # 3	69	168	154[1]
High Speed Test Cycle # 4	69	6278	6223[1]
Low Speed Test Cycle # 1	236	3370	3235[1]
Low Speed Test Cycle # 2	236	3924	3761[1]
Low Speed Test Cycle # 3	236	3347	3206[1]
New York City Cycle	464	4624	4602[1]
Speed Correction Factor 12	464	1829[1]	1833
Speed Correction Factor 36	464	39218	39066[1]
Full model Estimate[2]	3216	15129	15056

Lowest mean square prediction error on test cycle

[2] Full model estimate based on all cycles minus Bag1 and Bag3

4.4 *Comparison of Coefficient of Determination (and adjusted measure)*

As discussed previously, the coefficient of determination (r-square) is used to assess a models ability to explain the variation in carbon monoxide emissions. The traditional r-square value is obtained by regressing model predicted outputs onto actual emission measurements. To do these analyses, the BASIC program output (predicted and observed emissions from CALINE 4 and EMFAC 7F algorithms) were fed into Microsoft Excel spreadsheets for manipulation. The regression analysis tool was employed to do the regression analyses. The statistical methodology employed to estimate these measures is described below.

The sum of squares in a traditional analysis of variance (ANOVA) for a regression model is derived in the following manner:

$$y_{pred} = B_0 + B_1X_1 + B_2X_2 + error,$$

where;

y_{pred} = predicted value of carbon monoxide emissions,

X,, X_2 = observed explanatory variables,

B_0, B_1, B_2 = ordinary least squares estimated parameters,

error = disturbance *term.*

In ANOVA, the sum of squares possess two unique properties. The two properties are illustrated by the following relations:

1] $(Y_{obs} - Y_{ave}) = (Y_{pred} - Y_{ave}) + (Y_{obs} - Y_{pred})$, and

2] $\Sigma(Y_{obs} - Y_{ave})^2 = \Sigma(Y_{pred} - Y_{ave})^2 + \Sigma(Y_{obs} - Y_{pred})^2$,

where;

Y_{obs} = observed emission value,

Y_{pred} = predicted emission value,

Y_{ave} = average emission value,

$Y_{obs} - Y_{ave}$ = total deviation, or deviation of observed values around mean,

$Y_{pred} - Y_{ave}$ = deviation of fitted regression value around mean, and

$Y_{obs} - Y_{pred}$ = deviation of observed values around fitted regression equation.

The first property is somewhat intuitive, as we *can* prove it with simple addition. The second property, however, is less intuitive, and is extremely useful for the derivation of analysis of variance results. For a proof of sum of squares property 2, refer to Neter, Wasserman, and Kutner, 1990.

Following the traditional ANOVA approach, sums of squares are developed that describe the variation between model predicted carbon monoxide emissions and observed carbon monoxide emissions. To do this, we start by defining sums of squares as:

$\Sigma(Y_{pred} - Y_{ave})^2$ = sum of squared deviations of fitted regression value around sample mean (SSR),
$\Sigma(Y_{obs} - Y_{pred})^2$ = sum of squared deviations of observed values around fitted regression equation (SSE), and
$\Sigma(Y_{pred} - Y_{ave})^2 + (Y_{obs} - Y_{pred})^2$ = total sum of squared deviations (SST).

The coefficient of determination (r-square) can then be defined as:

$$\text{r-square} = SSR / SST = \Sigma(Y_{pred} - Y_{ave})^2 \; / \; [\Sigma(Y_{pred} - Y_{ave})^2 + \Sigma(Y_{obs} - Y_{pred})^2]$$

The r-square value is useful for indicating a model's ability to explain the variation in emission rates. However, it does not account for model's with different numbers of parameters being estimated. A model with a greater number of estimated parameters is more likely to explain variation just by nature of the computation of r-square, in other words, SSR can not become smaller with the addition of explanatory variables to a model. So, an r-square adjusted for the degrees of freedom associated with sums of squares is computed. The 'adjusted r-square' is defined with new terms as:

$$\text{adjusted r-square} = 1 - \left[\frac{n-1}{n-p}\right] \cdot \left[\frac{SSE}{SST}\right],$$

where;

n = sample size,
p = number of estimated parameters

The adjusted r-square values for the tested models are shown in tables 7 and 8. Table 7 shows the dis-aggregate analyses results, while table 8 shows the aggregated analyses results.

Table 7 shows that when individual vehicle emission values are used, both EMFAC 7F and CALINE 4 model algorithms explain a fair amount of the variation in carbon monoxide emissions, 69.3% and 68.7% respectively for full model estimates. The full model is not that sensitive to differences in parameters of the two model algorithms since n is so large, and so the more objective adjusted r-square values are not too different than regular r-squares, 68.6% and 69.1% respectively for CALINE 4 and EMFAC 7F. Essentially, there is no significant difference in predictive ability between the two algorithms.

Table 7: summary of R-Square and Adjusted R-Square for All Cycles:
Individual Vehicle Bag 2 and Idle Data

Cycle Name	Number of Vehicles Tested (n)	R-Square Value for CALINE 4[5] %	R-Square Value for EMFAC 7F[6] %	Adjusted R-Square Value for CALINE 4 %	Adjusted R-Square Value for EMFAC 7F %
Federal Test Procedure - Bag 1	464	65.6[1]	64.4	65.2[2]	63.2
Federal Test Procedure - Bag 2	464	90.7	100.0[1]	90.6	100.0[2]
Federal Test Procedure - Bag 3	464	84.9	85.4[1]	84.7	84.9[2]
Highway Fuel Economy Test	464	62.6	69.7[1]	62.2	68.7[2]
High Speed Test Cycle # 1	25	71.1[1]	70.0	63.5[2]	20.0
High Speed Test Cycle # 2	25	61.7'	59.8	51.6[2]	0
High Speed Test Cycle # 3	69	9.64	13.0[1]	2.47[2]	0
High Speed Test Cycle # 4	69	4.38	7.07[1]	0	0
Low Speed Test Cycle # 1	236	49.3[1]	40.3	48.2[2]	36.2
Low Speed Test Cycle # 2	236	53.9[1]	40.2	52.9[2]	36.1
Low Speed Test Cycle # 3	236	46.8[1]	26.5	45.6[2]	21.5
New York City Cycle	464	83.1[1]	77.1	82.9[2]	76.3
Speed Correction Factor 12	464	81.0	83.4[1]	80.8	82.8[2]
Speed Correction Factor 36	464	69.3[1]	68.6	69.0[2]	67.6
Full Model Estimate[7]	3216	68.7	69.3	68.6	69.1

[1] Highest R-Square value on test cycle

[2] Highest Adjusted R-Square value on test cycle

[3] On FTP-Bag 1 where average *speed* is 25.75 kph the terms in the function for EMFAC 7F drop *out*, allowing perfect fit to the data

[4] Since there were only 25 vehicles tested, the Adjusted R-Square became negative

[5] CALINE 4 model contains 6 estimated parameters

[6] EMFAC 7F model contains 16 estimated parameters

[7] Estimate of statistical parameters for Test on vehicles on all cycles except FTP Bag 1 and FTP Bag3

When we look at individual cycle predictive ability, however, the CALINE 4 algorithms are clearly superior, especially when we account for differences in the number of estimated parameters between the two model algorithms. Using the adjusted r-square criterion, the CALINE 4 model algorithms explain more of the variation on 8 out of 11 of the cycles (Bag 1 and Bag 3 omitted). These findings *suggest* that the 'modal' nature of the CALINE 4 algorithms combined with the two independent variables (Bag 2 and Idle rates) has more explanatory power than differentiating CO emissions by CARB's four technology groups. Furthermore, in light of the fact that the CALINE 4 algorithms were not estimated using the SCF data set (unlike the EMFAC 7F algorithms), the results are perhaps even more significant.

Table 8: Summary of R-Square and Adjusted R-Square for All Cycles: Aggregate Bag 2 and Idle Data

Cycle Name	Number of Vehicles Tested	R-Square Value for CALINE 4[2] %	R-Square Value for EMFAC 7F[3] %
Federal Test Procedure - Bag 1	464	0	4.3
Federal Test Procedure - Bag 2	464	0	0
Federal Test Procedure - Bag 3	464	0	0.9
Highway Fuel Economy Test	464	0	0.3
High Speed Test Cycle # 1	25	0	1.6
High Speed Test Cycle # 2	25	0	0.0
High Speed Test Cycle # 3	69	0	10.7
High Speed Test Cycle # 4	69	0	2.2
Low Speed Test Cycle # 1	236	0	1.6
Low Speed Test Cycle # 2	236	0	2.0
Low Speed Test Cycle # 3	236	0	2.6
New York C i Cycle	464	0	0.9
Speed Correction Factor 12	464	0	1.0
Speed Correction Factor 36	464	0	0.5
Full model Estimate[4]	4144	1.6[5]	2.0

[1] Highest R-Square Value

[2] R-Square is zero because the sum of squares of the regression function is zero, i.e. predictions are the same for one cycle

[3] R-Square gets explanatory power from variation between emission estimates from technology groups 1 through 4

[4] Estimate of Statistical Parameters for Test on All Cycles Except FTP Bag1 and FTP Bag3

[5] R-Square becomes non-zero due to emission estimate differences between cycles

When we consider the explanatory power of the model algorithms using aggregate data (see table 8), the results are drastically different. On individual cycle tests, the CALINE 4 algorithm has no explanatory power since all CO emission predictions are the same. Since the models are predicting nearly a flat response in carbon monoxide emissions, then the estimate for SSR approaches 0, while SSE approaches SST, resulting in a near zero estimate for r-square. The EMFAC 7F algorithms, however, retain some explanatory power from the different *speed* correction factor curves for the 4 technology groups. We see that the technology groupings have different effects based upon test cycle characteristics. These findings *suggest* that technology groupings are not stable across testing cycles. For instance, the 4 technology groupings do well to differentiate emissions on the **high-speed** test cycle #3, but do very little to explain variation for the New York City test cycle. We *can* not determine from these results weather the technology groupings are useful when disaggregate data is used, we *can* however, determine that in current practice, technology groupings are doing little in the way of improving across the board CO emission estimates from vehicle fleets.

4.5 Analysis of Residual Plots for C L I N E 4 and EMFAC 7F

The residuals plots for six cycles are shown in appendix F. The appendix currently **contains** residual plots the FTP Bag 1 Cycle, the Highway Fuel Economy Test cycle, the High-speed Test cycle **#3,** the Low-Speed Test cycle #1, the New York City cycle, and the **Speed** Cycle ***36.*** For each of these cycles, there are four residual plots: two each for the **EMFAC** 7F and *C L I N E* **4** models, one for both individual vehicle emission rates and one for fleet average emission rates.

The plots illustrate the nature of some **of** the deficiencies with the functional form of both the CALINE **4** and **EMFAC** 7F models. Some **of** the plots, for instance, illustrate increasing CO emission residual with increasing actual CO emissions. Plot **9** illustrates **this** 'funnel' **effect** well. This effect is generally caused by an independent variable **needing** a transformation, or a missing independent variable. It is likely that a log transformation of CO emissions would improve the normality **of** the residuals **shown** in plot **9.** Plot **22** on the other **hand,** exhibits fairly **normal** distribution **of** residuals. **This** suggests that we might reasonably be able to construct confidence and prediction intervals around the submodel beta **coefficients,** and emission predictions.

Some plots based upon individual vehicle emission rates show that there is a systematic trend. For example, plot ***5*** shows a systematic upward linear trend with increasing CO emissions. **This** suggests **a** missing explanatory variable, presence of outliers, or a needed variable transformation.

The effect of averaging *can* be seen by comparing the plots based on average emission values to those based **on** individual vehicle values. As predicted **carbon** monoxide emissions increase, the residuals also increase. In other words, emission under-prediction gets larger **as** emissions predicted by the model become larger. This *can* be explained by the averaging methodology employed by the CALINE **4** and **EMFAC** 7F models. Since the Bag **2** and Idle values used in the models are averages, the low emitting vehicles (emitters below the average emission value) **are** constantly **being** over-predicted, while the high emitting vehicles (emitters above the emission value) are being under-predicted. The 'straight' line residuals plot crosses the **x-axis** at the mean emission prediction value, the point where residuals **equal** zero. This systematic trend is **not** a desirable property from a statistical standpoint, since the model completely fails to capture the variation between vehicles, and **because** the residuals are far **from** normally distributed, which means that inferences about confidence **and** prediction intervals are invalid.

4.6 Impact Of The High-Emitters

Two problems arise from the high proportion and extremely influential high-emitters contained in the vehicle fleet. First, the proportion of high emitters has extreme influence on the computation of fleet average values, which in turn will impact the estimates of carbon monoxide emissions for the same fleet. **Second,** the utility of the models is over-stated since highemitters have undue influence on the computation of the r-square values. This problem *can* easily lead to mis-interpretation of the model assessment results. These problems are addressed in the following two sections.

4.6.1 High-emitter influence on computation of fleet averages

Since both the *CLINE* **4** and **EMFAC 7F** models rely on fleet average Bag **2** emission rates, we should require that Bag **2** averages truly represent vehicle fleet average Bag **2** rates. If for example, Bag **2** averages for the sample fleet were higher than those in the true fleet, the models would overestimate carbon monoxide emissions. The concern is, how much over or under estimation would occur from using an incorrect estimate of average Bag **2** emission rate?

To answer this question, we first must find an objective way to identify highemitting vehicles. We propose a methodology to identify high-emitting vehicles using the following assumptions. First, we assume that the FTP Bag **2** test procedure yields results that results in a normal distribution of emission rates in *grams* per mile. That is to say that the mean and median emission rate for the sample of vehicles tested on the **FTP** Bag **2** will be approximately equal. The variation, or spread of carbon monoxide emissions about the mean will be due to variations in test cycle characteristics, engine sizes, driving behavior, fuel quality, etc. The second assumption is that the addition of high emitting vehicles to this standard normal fleet will raise mean emission rates above the median emission rate, and will skew the normal distribution. The approach employed here to identify high-emitters is to rank order the sample fleet by emission rate, and then divide the high emitters from the 'normal' emitters using the criteria described above.

Unfortunately, using the above **procedure** is inadequate, since only a small portion of the cleanest vehicles exhibit behavior that follows a normal distribution. Instead, we had to employ a more subjective criteria to identify outliers, and *so* a cut-point of **62.13** *grams* per kilometer was used to separate normal from high-emitting vehicles. This cut-point was chosen since it is an *easy* to remember cut-point, and because it is not subject to variation in vehicle fleet composition. For example, an identification scheme employing the sample mean and one or two standard deviations from the sample mean is dependent upon the sample, and will vary across test samples, whereas using **62.13** *grams* per kilometer is a consistent means of comparison across samples.

Table 9 shows the breakdown of the highemitters contained in the Speed Correction Factor data set for CO. For example, when roughly **7.8%** of the vehicles exhibit test result emission rates greater than **62.13** *grams* per kilometer, their contribution to the total emission inventory for that fleet is roughly **72%.** Similarly, 3.5 **%** high emitters in the fleet contribute to **53 %** of the total emission inventory. In addition, the table shows that mean emission rates increase at a much faster rate than does the corresponding proportion of high-emitting vehicles. For

Table 9: Summary of High-Emitter Impact **on Emission** Inventory

Proportion of Vehicle Test Results above 62.13 grams / kilometer (% High-Emitters)	Mean Emission Rate (grams / kilometer)	Median Emission Rate (grams / kilometer)	High-Emitter Proportion of Total Emission Inventory (%)
7.85	16.66	1.80	72.27
7.50	16.15	1.79	71.27
6.80	15.10	1.74	69.04
4.63[1]	11.86	1.68	59.66
3.54	10.29	1.67	52.99
3.15	9.72	1.62	50.06
2.38	8.57	1.62	42.89

[1] proportion **of high-emitters (> 62.13 grams/kilometer) contained** in *speed* **correction factor data set for CO (Bag1 and Bag3 vehicles not included)**

example, increasing the proportion of high emitting vehicles **from** 3.5 % **to** 7.5 % corresponds to an increase in a mean emission rate increase **fkom** roughly **16** to **26** *grams* per mile.

To illustrate the extreme importance **of** the results provided in table 9, consider the following example. If we estimate that **3.5** 'YO of the vehicle fleet emit over **62.13** *grams* per kilometer, but in reality 7.5 % are high-emitters, then we **will** underestimate the true **mean** emission rate by roughly 5.9 *grams* per kilometer per vehicle (at the average ***speed*** of the test cycle). If we were to make **this** mistake **on** a region wide basis, we could expect roughly **an under-estimation** of CO emissions by about 10 metric tons per million vehicle kilometers of travel, or an under-estimation of the contribution of highemitter CO pollution to the total emission inventory by about 20%. The reverse effect would **occur** if the proportion of high emitters in the vehicle fleet **was** over-estimated.

4.6.2 High-emitter influence coefficient of determination

The proportion **of** highemitters in the vehicle fleet also dominate the r-square value, or the coefficient of determination. Table **10 below** shows the effect of various proportions of highemitters on the coefficient **of** determination value. We **see** that when **4.63** 'YO **of** the vehicle fleet emit greater than **62.13** *grams* per kilometer, then the CALINE **4** algorithms generate an r-square value of **67%,** but **if** we reduce the proportion **of high-emitters** by slightly more than **2%,** we reduce the r-square **by almost** 9%. **This** example illustrates a very important point about the role of high emitters in the CALINE **4** and **EMFAC** 7F algorithms: Since highemitters have such extreme emission values compared to **'normal'** emitting vehicles, their presence in the **data** set (and fleet) dominate the **functional** form and least **squares** fit **of** the regression model. What dominates the model, furthermore, are the differences between **normal** and high-emitters, while the subtle differences between normal emitters are **drowned** in the estimation process.

Table 10: Summary of High-Emitter Impact on Coefficient of Determination

Proportion of Vehicle Test Results above 62.13 grams / kilometer (High-Emitters) (%)	CALINE 4 Algorithm Correlation Coefficient (r)	CALINE 4 Algorithm Coefficient of Determination (R-Square)	Number of Observations (n)
4.63[1]	0.82	0.67	4144
2.38	0.76	0.58	4064
0	0.68	0.47	3981

[1] Proportion of high-emitters (> 62.13 grams/kilometer) contained in *speed* correction factor data set for *CO* (Bag1 and Bag3 vehicles not included)

The extreme influence of high-emitters in the fleet and in the fit of the models is problematic for several reasons, both from a statistical and a practical standpoint. First, what becomes most important statistically are independent variables that help determine high-emitter *status*. These might include driving cycle characteristics such as proportion of high acceleration events and idle, but might also include fuel delivery technology, presence of tampering, accumulated vehicle mileage, operating condition of the vehicle, and several others. Unfortunately, CALINE 4 and EMFAC 7F include a limited number of these 'explanatory' variables in their formulation, CALINE 4 having a slight advantage over EMFAC 7F. Variables such as presence of tampering, accumulated mileage, and condition of vehicle are not explicitly included in the model, therefore a large portion of the likely 'causal' factors are not present.

Furthermore, the subtle differences in emission behavior between similar vehicles becomes un-important, since the highemitters have such extreme influence. In effect, what we want to know about emission profile differences between 'similar' vehicles is dwarfed statistically by difference between normal and high emitters.

From a practical standpoint, using models that are ultra-sensitive to assumptions in vehicle fleet composition leads to great potential for inaccurate emission predictions. This holds true for regional modeling applications, as well as local project analyses. Misrepresentation of the proportion of highemitters in a regional vehicle fleet *can* lead to large over or under predictions of emission inventories or impacts.

5 Assessment of IVHS (Washington and Guensler, 1994)

Previous research has concluded that one of the most likely technology bundles to improve air quality are Advanced Traffic Management Systems (Washington, Guensler, Sperling, 1993). *As* the name implies, ATMS employ computer control technologies to 'optimize' or smooth traffic flows on a transportation network. Examples of ATMS technologies are real-time traffic signal network optimization, real-time ramp metering, and electronic vehicle tolling via automatic vehicle identification technologies (AVI). These computer controlled systems are designed to reduce congestion levels; minimize system-wide delay levels, and generally smooth vehicular flows. **ATMS** technology bundles also include various signal actuation bundles, incident detection, rapid accident response, and integrated traffic management.

Electronic toll collection, the topic of this paper, aims to smooth traffic flows by implementing advanced communications technologies between roadways and vehicles. If conventional tolling operations performed on bridges or tolled turnpikes were replaced with automatic and transparent vehicle identification and debiting, for example, then toll plaza induced delays experienced by motorists could be eliminated. The elimination of these activities would further result in fewer decelerations, idling, and acceleration events prevalent under conventional tolling operations. These 'modal' activities, representing high load and power conditions, have been shown to contribute significantly to the production of emissions from motor vehicles (LeBlanc, et al., 1994; CARB, 1991; Benson, 1989; Groblicki, 1990; Calspan Corp., 1973a; Calspan Corp., 1973b; Kunselman, et al., 1974). In fact, one sharp acceleration may cause as much pollution as does the entire remaining trip (Carlock, 1992). This suggests that a small percentage of a vehicle's activity may account for a large share of it's emissions (LeBlanc, et. al., 1994). In addition, longer enrichment events are more highly correlated with large emission excursions than are shorter events (LeBlanc, et. al., 1994), and furthermore, deceleration events are capable of producing significant emissions (Darlington, et al., 1992). In contrast to cold *start* emissions that occur over a period of minutes, acceleration and deceleration related emissions occur over a period of a few seconds.

Using a modified version of the CALINE 4 modal model, we assess the impacts of electronic tolling using AVI. The goal is to quantify the expected CO emission differences between a toll-plaza and the no toll-plaza, or AVI scenario. In addition, the expected variation in these benefits is approximated given current limitations of the vehicle emissions data.

5.1 Experimental Design for AVI Analyses

The modified CALINE 4 algorithms are employed to estimate the difference in CO emissions between a vehicle encountering a conventional toll plaza, and uninterrupted flow experienced when automatic vehicle identification tolling operations are used. To perform these comparisons, a toll plaza is first simulated on a typical transportation link. The link could be a typical tolled bridge entrance, or an entrance to a tolled highway or freeway. The toll plaza design follows that described by Lin (1994), representing a Gate type 'C' operating at level of service A. Under these conditions, the average vehicle experiences about 6 to 8 seconds of delay waiting for previously queued vehicles (Lin, 1994). Since the carbon monoxide emission estimates from vehicles encountering toll plazas are done on a per-vehicle basis, and because level of service A is assumed in the analyses, demand greater than capacity induced congestion delay is considered here.

To simulate vehicular activity under the two different scenarios, speed-time profiles were developed for four different vehicle trajectories. Table 11 displays some characteristics of the four speed-time profiles. Two speed-time profiles were developed for both the toll plaza and no toll plaza (AVI) scenarios, one for drivers exhibiting 'aggressive' driving behavior and one for drivers exhibiting 'normal' driving behavior. For the no toll plaza scenario (AVI), aggressive drivers 'floated' around their 96.56 kph target *speed* by 4.83 kph with 1.61 kph/sec maximum acceleration and deceleration rates, while 'normal' drivers were assumed to 'float' around their 96.56 kph target *speed* by 1.61 kph/sec with 0.80 kph/sec maximum acceleration and deceleration rates. Aggressive driving behavior for the toll-plaza scenario included acceleration and deceleration rates of about 7.24 kph/sec, while normal driving behavior includes acceleration and deceleration rates of 3.22 kph/sec. These rates agree with current car following *and* instrumented vehicle research that has substantiated acceleration and deceleration rates as high as 9.66 kph/sec (Cicero–Fernandez and Long, 1993). All vehicles were assumed to begin and end their speed-time trajectory at a constant *speed,* either 64.38 kph, 80.47 kph, or 96.56 kph

Using a slightly modified version of the BASIC computer program previously discussed, the new cycles were 'parsed' into discrete modes of acceleration, deceleration, *cruise,* and idle. The program is also used to apply the modified CALINE 4 algorithms and estimate CO emissions from the generated speed-time profiles.

All of the vehicles contained in the current Speed Correction Factor Data Base were used to estimate CO emissions from a 'fleet' of vehicles passing through the toll plaza and AVI scenarios. After several outlying test results were discarded, 460 remaining vehicles were used to approximate the vehicle fleet.

Since the modal model *can* predict CO emission contributions from acceleration and deceleration events, the resulting carbon monoxide emission predictions reflect the effect of microscopic traffic flow adjustments under the two different scenarios. The results of the modeling runs *can* be seen in table 12. The model predicts that 'aggressively' driven vehicles entering the segments at 96.56 kph will emit about 154 more *grams* of *CO* with a mandatory stop toll-plaza than with AVI (on average). The median difference is about 23.37 *grams* of *CO,* which suggests that the distribution of CO emissions from this fleet of vehicles is non-normal and heavily skewed by influential *'duty'* vehicles. The standard deviation under the same scenario, about 446 *grams,* also illustrates the extreme influence of these high emitting vehicles.

Table 11: Characteristics of Assumed Vehicle Speed-Time Profiles for Toll-Plaza and AVI Scenarios

Cycle Description	Maximum Acceleration and Deceleration Rates (kph/sec)	Speed-Time Profile Distance in (Kilometers)	Speed-Time Profile Length (Seconds)	Speed-Time Profile Average Speed (kph)
Toll Plaza,		64.38 kph - 0.528	64.38 kph - 46	6438 kph - 41.4
'Aggressive' Driving	7.24	80.47 kph - 0.774	80.47 kph - 55	80.47 kph - 50.7
		96.56 kph - 0.834	96.56 kph - 53	96.56 kph - 56.7
Toll Plaza,		64.38 kph-0.518	64.38 kph - 56	64.38 kph - 33.3
'Normal' Driving	3.22	80.47 kph - 0.782	80.47 kph - 67	80.47 kph - 42.0
		96.56 kph - 0.832	96.56 kph - 66	96.56 kph - 45.4
AVI,		64.38 kph - 0.515	64.38 kph - 29	64.38 kph - 63.9
'Aggressive' Driving	1.61	80.47 kph - 0.782	80.47 kph - 35	80.47 kph - 80.5
		96.56 kph - 0.827	96.56 kph - 31	96.56 kph - 96.1
AVI,		64.38 kph - 0.518	64.38 kph - 29	64.38 kph - 64.4
'Normal' Driving	0.80	80.47 kph - 0.782	80.47 kph - 35	80.47 kph - 80.5
		96.56 kph - 0.832	96.56 kph - 31	96.56 kph - 96.6

The table also illustrates that 'normal' driving behavior, i.e. vehicle activity incorporating moderate acceleration and deceleration rates, results in much smaller CO emission rate differences. These findings agree with current literature that has identified high emission rates with extreme modal activity.

5.2 Automatic Vehicle Identification Analyses Results

These findings suggest that reductions in CO emissions can be realized through the application of an Intelligent Vehicle and Highway System (IVHS) technology. This IVHS application, the replacement of conventional toll plazas with automatic vehicle identification technologies to debit passing vehicles, has been previously identified as an application with likely benefits to air quality. Influential factors include traffic volumes, emission characteristics of the vehicle fleet, and driving behavior of individuals under the different scenarios. For example, drivers may be inclined to drive aggressively under the toll plaza scenario, since it requires drivers to stop and queue, and then merge with traffic exiting adjacent toll plazas. These same drivers, however, may not be inclined to drive aggressively with the AVI scenario, since there is no stopdelay experienced.

Table 13 demonstrates the range of CO reduction estimates. The table shows the two extreme scenarios: normal toll-booth driving (mild acceleration and deceleration rates) replaced with aggressive AVI driving (unsteady throttle position during cruise); and aggressive toll-booth driving replaced with normal AVI driving. The table demonstrates that emission reduction estimates are extremely sensitive to assumptions about driving behavior. For example, assuming 80.47 kph entry and exit speeds, and 22,000 average daily traffic volume per lane, we would expect anywhere from 57 to 5300 metric tons of CO reduction per year per lane from implementation of AVI.

Table 12: Carbon Monoxide Differences Between Toll Plaza and AVI Scenarios.

Driving Behavior with Toll-Plaza	Driving Behavior with AVI	Mean Carbon Monoxide Difference (grams / vehicle)	Median Carbon Monoxide Difference (grams / vehicle)	Standard Deviation in Carbon Monoxide Difference (grams)
Aggressive	Normal	64.38 kph - 19.26	64.38 kph - 3.36	64.38 kph - 54.26
		80.47 kph - 658.36	80.47 kph - 100.24	80.47 kph - 1912.19
		96.56 kph - 159.37	96.56 kph - 24.18	96.56 kph - 461.34
Aggressive	Aggressive	64.38 kph - 18.63	64.38 kph - 2.93	64.38 kph - 53.51
		80.47 kph - 655.88	80.47 kph - 99.96	80.47 kph - 1906.19
		96.56 kph - 153.72	96.56 kph - 23.37	96.56 kph - 446.06
Normal	Normal	64.38 kph - 5.29	64.38 kph - 1.03	64.38 kph - 13.86
		80.47 kph - 9.57	80.47 kph - 1.79	80.47 kph - 25.82
		96.56 kph - 15.29	96.56 kph - 2.81	96.56 kph - 42.09
Normal	Aggressive	64.38 kph - 4.66	6438 kph - 0.86	64.38 kph - 12.88
		80.47 kph - 7.08	80.47 kph - 1.28	80.47 kph - 19.61
		96.56 kph - 9.64	96.56 kph - 1.75	96.56 kph - 26.70

These estimates agree well with those found in field studies performed in Massachusetts and New Jersey (Clean *Air* Act Corporation, 1993).

The results *suggested* here indicate that application of electronic toll collection in lei of traditional toll plaza's *can* bring about significant reductions in carbon monoxide emissions from motor vehicles. The reductions however, are dependent upon driving behavior, approach *speeds*, traffic volumes, and the characterization of the vehicle fleet. In addition, modeling uncertainty will likely increase the range of uncertainty brought about by the previously mentioned factors. For instance, confidence interval analyses or Monte Carlo simulation techniques could capture the random error (and uncaptured systematic errors) associated with model predictions.

The dynamometer tested vehicles modeled in these analyses are likely not representative of the current vehicle fleet. As the 'typical' vehicle fleet in one area is likely different than another, i.e. Los Angeles versus New York City, it is difficult to characterize any fleet with certainty. The most critical factor in vehicle fleet representation is the proportion of highemitting vehicles. The effect of highemitters in the modeled fleet *can* be seen in table 12. The fleet mean response is much higher than the median response, which indicates that high emitters are extremely influential in the statistical estimates of model parameters. The effect of these highemitters on statistical robustness is currently being investigated.

In the analyses presented here, congestion is assumed to not exist (outside of the toll-booth induced congestion), but practical experience shows that tolled links *can* operate in the congested flow regime, and we need to consider

Table 13: Expected CO Reductions (Metric Tons per Year) with Application of Electronic Toll Collection

Scenario 1: Normal Toll-Booth Driving and Aggressive AVI Driving			
Daily Traffic Volume Per Lane	96.56 kph	80.47 kph	64.38 kph
25,000	88	65	42
22,000	77	57	37
19,000	67	50	32
1,600	5.6	4.1	2.7
Scenario 2: Aggressive Toll-Booth Driving and Normal AVI Driving			
Daily Traffic Volume Per Lane	96.56 kph	80.47 kph	64.38 kph
25,000	1500	6000	180
22,000	1300	5300	150
19,000	1100	4600	130
1,600	93	380	11

these congestion effects on emission estimates. This can be approached by expanding this analyses to include micro-simulations of traffic flow on a series of links.

Finally, the behavioral changes that might be induced by application of IVHS technologies needs to be addressed. For example, previous peak-period congestion induced by toll-plazas, now eliminated by application of electronic tolling using AVI, might make the travel route more attractive to motorists. If this short-term increase in peak period level of service attracts 'new' motorists to the facility, then the projected carbon monoxide emission reductions may be partially or fully offset by increased traffic and congestion. These questions can be partially addressed through field studies of electronic toll collection pilot projects, and perhaps through the use of advanced network simulation modeling.

6 Discussion of Results:

This research effort **has** identified some modeling deficiencies that are inherent in the algorithms contained in the CALINE **4** and EMFAC 7F emissions models. Before the deficiencies are discussed, the authors should first reiterate the framework for application of the two models being discussed. The CALINE **4** model is used primarily for project-level analyses, and is intended for microscale emission impact assessment. EMFAC 7F, on the other **hand,** is primarily used in regional analyses, and is employed to determine emission inventories. **This** distinction is important when we consider their practical application. For example, if we desire to estimate **an** emission inventory, then predicting the *true mean* emission rate based on average ***speed*** on system links **will** sufiice to provide a good approximation of the regional emissions **(this** is unlikely however). If, on the other **hand,** we desire to know the emission impacts of flow smoothing interventions such **as** variable message signing, then the average ***speed*** methodology regularly employed **will** not be sufficient. The intended application **of** any emissions model, then, becomes a critical component in determining it's adequacy.

A problem that plagues current air quality and transportation planners is that 'regional' models **are** used to **assess** the impacts of solutions that cannot adequately be assessed with the models. In addition, planners using the models have no way of **knowing** weather their output is accurate or not. For these **reasons,** we **need to** incorporate confidence intervals in emission model outputs (both regionally and locally), and adopt a modeling regime that *can* offer **this** type of output. Only then, *can* **truly** informed policy decisions be made with regard to air quality regulation and enforcement.

We have shown several important effi of the current modeling methodologies, and have compared the performance of EMFAC **7F** and CALINE **4** emission estimating algorithms. Among the modeling deficiencies are the impact of high-emitters on model functional **forms,** and also **on statistical** robustness **of** the two model **algorithms.** The impact of highemitters on the vehicle fleet was shown to have extreme influence on emission estimates, and proves to be a critical **factor** in sensitivity analyses. To illustrate the extreme impact that **high-**emitters have on the models, pretend you are a judge at a taste test for delicatessen made turkey sandwiches. Your job is to distinguish the subtle differences in sandwich preparation techniques employed by the **competing** deli's. **To** your surprise, however, a contest saboteur **has** loaded **all** of the deli sandwiches with jalapeno peppers. It is now impossible to **discern** what preparation techniques result in a superb turkey sandwich. All of these **issues** (barring turkey sandwich judging contests) will be **discussed** in greater detail in the **final** report.

When making across-the-board comparisons between the true EMFAC **7F** and CALINE **4** algorithms, we ***see*** that CALINE **4** and EMFAC **7F** perform similarly on almost all measures, with the CALINE **4** performing slightly better on average. This advantage in performance is attributed to the inclusion of an idle factor in the CALINE 4 model algorithms, and a simpler model functional form. In addition, the CALINE 4 model algorithms include more 'causal' variables such as speed acceleration product, and contributions from modal events. CALINE 4 emission prediction algorithm performance is perhaps more impressive when we consider the fact that the EMFAC 7F model algorithms were estimated using the SCF data base, while CALINE 4's algorithms were estimated using a much older and smaller data set. Considering both statistical and practical factors, the CALINE 4 model is a more sound and robust approach to estimate emissions from vehicles on specific links than is the approach employed in EMFAC 7F.

When using individual vehicle emission test results in the model algorithms, we see a substantial improvement in overall algorithm performance. The ability to capture variation between individual vehicles in a hypothetical fleet is made possible, and the explanatory power of both models improves by more than an order of magnitude. This methodology appears to be a far superior approach to modeling emissions, and significantly improves the robustness of both model algorithms.

The utility of the improved CALINE 4 model algorithms are demonstrated with the assessment of an applied IVHS technology; electronic toll collection using automatic vehicle identification. The model algorithms are applied to a two alternative scenario: a link with a conventional toll plaza, or the same link with electronic toll collection. The results demonstrate that the improved CALINE 4 model algorithms can resolve emissions under two different driving scenarios involving various speed-time profiles. The algorithms predict emission differences based upon contributions from deceleration, idle, and acceleration events under the conventional toll plaza scenario. The results suggest that adequately modeling subtle changes in speed-time profiles is plausible, and that micro-simulation modeling techniques can be upgraded to meet the challenge.

7 Conclusions and Recommendations:

In the short term, the next CALINE 4 model improvement effort should include an upgrade to its modal emission algorithms. Among its improvements should be inclusion of individual vehicle Bag 2 and Idle rates, recalculation of the modal model coefficients (verification), and full use of the 'modal' model algorithms through traffic simulation (not just intersections). Each of these are discussed below.

Including individual vehicle Bag 2 and Idle rates into model algorithms would require several steps. First, a sample of tested vehicles (i.e. the speed correction factor data set) would need to be broken down into subsamples by emitter class. For example, 4 or 5 sub-samples could be generated separating vehicles by emission results on testing cycles, with classes of ultra-high emitters, high emitters, normal emitters, low emitters, and ultra-low emitters. These subsamples of vehicles would constitute the sample 'bins' from which local vehicle fleets could be approximated. Then, support files would be included with the CALINE 4 software, which would contain the emission information necessary for subroutine calls from the main program. These files would contain individual vehicle Bag 2 and Idle test data The CALINE 4 algorithms would be modified to call the support files so modal emission contributions from the hypothetical fleets could be calculated. Finally, the user of the CALINE 4 model could select default fleet characteristics (*dirty* vehicle fleet), or could input local fleet characteristics by specified characteristics. This formulation would require careful classification of emitters subsamples in the previous step. This overall improvement to the CALINE 4 algorithms would enable the CALINE 4 model to assess the impacts of projects that only offer flow smoothing, an assessment that currently lacks the appropriate tools.

The coefficients contained in the CALINE 4 model's algorithms were estimated using an older and smaller data set. These coefficients could be verified against a new data set (i.e. the SCF data set) to see if they still characterize emissions behavior of these vehicles. Using mathematical search procedures, the coefficients could be simultaneously adjusted to see if they are still appropriate. There is reason to believe that improvement of the coefficients would further improve the robustness of CALM 4's explanatory power, providing further improved estimates of CO emissions from modal events.

The CALINE 4 model algorithms should be considered for use on all assessments, not just those incorporated with intersections. Since the outputs from the EMFAC 7F and MOBILE models are questionable, especially if the previous improvements are incorporated in the CALINE 4 model algorithms, their use will increase the uncertainty associated with 'cruise' related emissions on roadway segments. The 'cruise' emission factor incorporated in the CALINE 4 model is likely to yield more accurate results than the method employed currently.

In the long term, a micro-simulation model should be developed that utilizes car-following theory (instead of user specified vehicular activity as in CALINE 4) to simulate vehicular fleet behavior. At the same time, speed-time profiles should be developed by facility type and level of service (or some appropriate surrogate), that can then be used to develop emission testing cycles. The results from the testing cycles (second by second emissions) can then be used to estimate new emission models appropriate for facility type and level of service. The combined modal activity/facility type/level of service dependent emission model could be incorporated with the micro-simulation model to construct a robust project level emission impact tool.

We must keep in perspective, however, the regulatory environment when considering recommendations. For there to be an incentive to develop more robust local and regional models, the regulators must demonstrate that they are willing to approve the use of these models for future conformity and emission impact analyses. Although there exists motivation for new model development from a theoretical and academic standpoint, new models will be of no use to practicioners if they are not allowed to use them. We must urge regulatory agencies such as the CARB and the USEPA to remain flexible (yet rigorous) when considering new models for the extremely timely and difficult air quality analyses now predominant in non-attainment regions throughout the United States.

8 Further Research Needs:

To better understand the impact and role of highemitters in the vehicle fleet, we need to gain a better understanding of the variability between regions. This is not as easy as using remote sensing technologies, since they measure CO concentrations (not grams / mile), and they capture only a snapshot in time. Research of this nature would involve random testing from vehicle fleets in various regions. Factors such as tampering rates, average condition of vehicles, average age of vehicles, and types of vehicles would likely play a large role in the results.

We also need to gather second-by-second emission data from vehicles, with the explicit goal of estimating comprehensive emission impact and inventory models. Factors such as fuel variability, differences in drivers, and impact of cycle characteristics should be directly addressed A comprehensive effort to develop this type of model should be undertaken with the goal to replace both the modeling methodology in MOBILE and EMFAC.

Research into cycle characteristics needs to continue to be undertaken. There are many lingering questions that have yet to be addressed, such as: Is driving behavior different across regions, cities, or states; Is driving behavior different across facilities; what driving behavior is critical to emission production? These questions are beginning to be addressed, but need further attention.

We need to reconsider the link between transportation activity models (micro-simulation and regional) and air quality models (local impact and regional). Currently, the outputs from the transportation activity models are seriously deficient for inputs into air quality models. The link between these two models is absolutely and fundamentally critical to the accurate assessment of emission inventories. If an overall improvement to the air quality models is not accompanied by a similar improvement in transportation activity models, then we will gain little in air quality analyses. We must identify the outputs that are necessary from activity models to be useful for use in air quality models.

Finally, the enormous computing power at our disposal should be taken advantage of. The current programs used to simulate traffic and to estimate vehicular emissions do not come close to pushing the envelope of current computing power capabilities. For example, a small city can be modeled on a personal computer with a minimal hardware configuration, and similarly for an air quality model. Upgraded and newly developed transportation activity and emissions impact/inventory models should be done with the help of computer scientists familiar with the latest technologies and hardware.

References

Benson, Paul (1989). "CLINE 4, A Dispersion Model For Predicting Air Pollutant Concentrations Near Roadways" Federal Highway Administration Report No. FHWA/CA/TL-84/15.

Calspan Corporation (1973a). "A Study of Emissions from Light-Duty Vehicles in Six Cities; Buffalo, NY"; Prepared for the Environmental Protection Agency (Document #APTD-1497), Office of' Mobile Source Air Pollution Control; Ann Arbor, MI; March 1973.

Calspan Corporation (1973b). "Automobile Exhaust Emission Surveillance (PB-220 775); Buffalo, NY"; Prepared for the Environmental Protection Agency (Document #APTD-1544), Office of Mobile Source Air Pollution Control; Ann Arbor, MI; May 1973.

CARB (1991), California Air Resources Board; Modal Acceleration Testing; Mailout No. 91-12; Mobile Source Division; El Monte, CA; March 20, 1991.

Carlock, Mark (1992). "Overview of Exhaust Emission Factor Models". In: Proceedings, Transportation Modeling: Tips and Trip Ups; *Air* and Waste Management Association; Pittsburgh, PA; March 1992.

Cicero-Fernandez, Pablo, Jeffrey Long (1993). "Modal Acceleration Testing on Current Technology Vehicles". Presented at the specialty conference: The Emission Inventory, Perception and Reality. Pasadena, CA. October 1993.

Clean Air Act Corporation (1993). "Proposed General Protocol for Determination of Emission Reduction Credits Created By Implementing *An* Electronic "Pike Pass" System On a Tollway". Prepared for NorthEast States for Coordinated *Air* Use Management, December 9, 1993.

Groblicki, Peter J.; Presentation at the California *Air* Resources Board Public Meeting on the Emission Inventory Process; General Motors Research Laboratories; Warren, MI; November 5,1990.

Lin, Feng-Bor (1994). "Level of Service Analysis of Toll-Plazas on Freeway Main Lines". Journal of Transportation Engineering, Vol. 120, No. 2. Mar./Apr. 1994.

LeBlanc, David C., Michael D. Meyer, F. Michael Saunders, James A. Mulholland (1994). "Carbon Monoxide Emissions From Road Driving: Evidence of Emissions Due to Power Enrichment". Presented at the 73rd Transportation Research Board Annual Meeting, January 9 - 13,1994. Washington D.C.

Guensler, Randall (1993). “Vehicle Emission Rates and Average Vehicle Operating Speeds”. A dissertation submitted to the University of California at Davis Graduate School, Davis, CA 95616.

Kunselman, P., H.T. McAdams, C.J. Domke, and M.E. Williams; Automobile Exhaust Emission Modal Analysis Model; Calspan Corporation; Buffalo, NY; Prepared for the Environmental Protection Agency (Document 460/3-74-005), Office of Mobile Source Air Pollution Control; Ann Arbor, MI; January 1974.

Neter, Wasserman, ‘and Kutner (1990). *Applied Linear Models.* Richard D. Irvin, Inc.

Washington, Simon, Randall Guensler, and Daniel Sperling (1993). “Assessing the Emission Impacts of IVHS in an Uncertain Future”. Proceedings of the World Car 2001 Conference, Riverside CA. The Center for Environmental Research & Technology, University of California Riverside.

Washington, Simon, and Randall Guensler (1994). “Carbon Monoxide Impacts of Automatic Vehicle Identification Applied to Electronic Vehicle Tolling Operations”. Proceedings of the National Policy Conference on Intelligent Transportation Technologies and the Environment, Hubert Humphrey Institute of Public Affairs, University of Minnesota. June 6 and 7,1994. Forthcoming.

Wood, Dick, and John Nguyen (1993). “Air Quality Impacts of Ramp Metering”. State of California Department of Transportation, Division of New Technology, Materials, and Research. Draft Minor Research Report 65332-638005-32140. August, 1993.

Appendix A: BASIC Emission Analysis Program Code

```
REM**************************************************************************
REM**************************************************************************
REM***                                                                    ***
REM***                                                                    ***
REM***          UC DAVIS MODAL EMISSION ANALYSIS MODEL                    ***
REM***          WITH CORRECTED COEFFICIENT & OBSERVED/PREDICTED           ***
REM***          FILE  (CORRELATION COEFFICIENTS)                          ***
REM***                                                                    ***
REM**************************************************************************
REM**************************************************************************



REM*******************VARIABLE INITIALIZATION/DEFINITION*******************

I = 0:                  REM     COUNTER FOR STEADY-STATE EVENT LENGTH (SECS)
J = 1:                  REM     COUNTER FOR STEADY-STATE EVENT NUMBER
K = 0:                  REM     COUNTER FOR EMISSION FILES
L = 0:                  REM     COUNTER FOR ANOVA RESULTS SUBROUTINE
M = 0:                  REM     RATIO VARIABLE FOR PROGRESS PROMPT
O = 1:                  REM     COUNTER VARIABLE FOR PROGRESS PROMPT
ACCCNT = 0:             REM     COUNTER FOR ACCELERATION EVENTS IN SUMMARY OUTPUT
ANSWER = 1:             REM     USER GIVEN VARIABLE FOR BAG 2 AND IDLE INFO TYPE
AVGSPEED = 0:           REM     INITIALIZE AVERAGE SPEED TO ZERO
AVGCYCSPD = 0:          REM     AVERAGE CYCLE SPEED OF COMPARISON CYCLE
AVGACCEL = 0:           REM     INITIALIZE AVERAGE ACCELERATION TO ZERO
BAG 2 = 0:              REM     FTP BAG 2 EMISSIONS IN GRAMS PER SECOND
BAG2RES = 0:            REM     FTP BAG 2 EMISSIONS IN GRAMS PER MILE (INPUT BY USER)
BAG2AVE = 0:            REM     AVERAGE BAG 2 RESULT FOR FLEET ON GIVEN CYCLE
CYCLNUM = 0:            REM     INPUT BY USER, THE CHOSEN CYCLE NUMBER
CID = 0:                REM     CUBIC INCH DISPLACEMENT OF VEHICLE
CRIT = 0:               REM     USED FOR STORING CURRENT LOOP'S MODE TYPE
COUNT = 1:              REM     COUNTER FOR PREVSPD AND FOR CYCLE SECONDS
COEFF1 = 0:             REM     COEFFICIENT #1 IN CALINE ACCELERATION FACTOR
COEFF2 = 0:             REM     COEFFICIENT #2 IN CALINE ACCELERATION FACTOR
COEF1 = 0:              REM     COEFFICIENT #1 IN EMFAC 7F MODEL FUNCTION
COEF2 = 0:              REM     COEFFICIENT #2 IN EMFAC 7F MODEL FUNCTION
COEF3 = 0:              REM     COEFFICIENT #3 IN EMFAC 7F MODEL FUNCTION
COEF4 = 0:              REM     COEFFICIENT 64 IN EMFAC 7F MODEL FUNCTION
CORRC = 0:              REM     CORRELATION COEFFICIENT FOR CALINE MODEL ON A CYCLE
CRUZCNT = 0:            REM     COUNTER FOR CRUISE EVENTS €OR SUMMARY OUTPUT
CUTRATE = .6:           REM     INSTANTANEOUS ACCELERATION CUT-OFF RATE
CYCLENTOT = 0:          REM     TOTAL CYCLE LENGHT IN SECONDS
CYCLENTOTI = 0:         REM     CYCLE LENGHT TOTALS BY MODE FOR SUMMARY OUTPUT
CYCLENTOTA = 0:         REM     CYCLE LENGHT TOTALS BY MODE €OR SUMMARY OUTPUT
CYCLENTOTC = 0:         REM     CYCLE LENGHT TOTALS BY MODE €OR SUMMARY OUTPUT
```

```
CYCLENTOTD = 0:          REM    CYCLE LENGHT TOTALS BY MODE FOR SUMMARY OUTPUT
DEN1C = 0:               REM    DENOMINATOR FACTOR OF CALINE CORRELATION COEFFICIENT FOR ALL
VEHICLES ON CYCLE
DEN2 = 0:                REM    DENOMINATOR FACTOR OF CORRELATION COEFFICIENT FOR EMFAC 7F &
CALINE FOR ALL VEHICLE ON CYCLE
DECELCNT = 0:            REM    COUNTER FOR DECELERATION EVENTS FOR SUMMARY OUTPUT
ENDLOOP = 0:             REM    LENGTH OF PARENT CYCLE (INPUT BY PROGRAM)
EMISESQ = 0:             REM    SQUARED EMFAC 7F ESTIMATED EMISSIONS FROM A VEHICLE ON A CYCLE
EMISSCAL = 0:            REM    TOTAL EMISSIONS ESTIMATED BY CALINE MODEL FOR ONE VEHICLE
EMISSACT = 0:            REM    BAG2 BASED EMISSION RESULTS FOR ONE VEHICLE
EMISSENEAC = 0:          REM    TOTAL EMISSIONS ESTIMATED BY EMFAC 7F MODEL FOR ONE VEHICLE
EMISSACTl = 0:           REM    ACTUAL NON-IDLE EMISSIONS BASED ON BAG2 TEST RESULT
EMISSACTZ = 0:           REM    ACTUAL IDLE EMISSIONS BASED ON BAG2 TEST RESULT
EMISSITOT = 0:           REM    TOTAL CALINE EMISSION ESTIMATE FOR IDLE EVENTS
EMISSCTOT = 0:           REM    TOTAL CALINE EMISSION ESTIMATE FOR CRUISE EVENTS
EMISSATOT = 0:           REM    TOTAL CALINE EMISSION ESTIMATE FOR ACCEL EVENTS
EMISSDTOT = 0:           REM    TOTAL CALINE €MISSION ESTIMATE FOR DECEL EVENTS
EMISSTOT = 0:            REM    TOTAL CALINE EMISSION ESTIMATE FOR CYCLE EMISSIONS
FINJ = 0:                REM    FUEL DELIVERY TYPE, 1=PORT, 2=CARBURETOR, 3=THROTTLE BODY
IDLECNT = 0:             REM    COUNTS IDLE EVENTS FOR SUMMARY OUTPUT
IDLEFACT1 = 0:           REM    IDLE EMISSION FACTOR IN GRAMS/MINUTE (INPUT BY USER)
IDLEFACT2 = 0:           REM    IDLE EMISSION FACTOR IN GRAMS/SECOND
IDLEAVE = 0:             REM    AVERAGE FLEET IDLE EMISSION FACTOR FOR GIVEN CYCLE
LASTSPD = 0:             REM    USED FOR CALCULATING ACCELERATION
LASTSSUM = 0:            REM    USED FOR STORING PREVIOUS SPEED OF EVENT
LASTCRIT = 0:            REM    USED FOR STORING PREVIOUS LOOP'S MODE TYPE
MODYR = 0:               REM    MODEL YEAR OF VEHICLE TESTED
MEANDIFF1 = 0:           REM    DIFFERENCE BETWEEN CALINE AND ACTUAL EMISSION MEANS
MEANDIFF2 = 0:           REM    DIFFERENCE BETWEEN EMFAC 7F AND ACTUAL EMISSION MEANS
MEANEMISSA = 0:          REM    MEAN ACTUAL EMISSION FOR MULTIPLE RUN
MEANEMISSC = 0:          REM    MEAN CALINE EMISSION FOR MULTIPLE RUN
MEANEMISSE = 0:          REM    MEAN EMFAC 7F EMISSION FOR MULTIPLE RUN
MSPEC = 0:               REM    MEAN SQUARED PREDICTION ERROR FOR CALINE MODEL ON A CYCLE
NUMCYCLE = 0:            REM    NUMBER OF ENGINE CYCLINDERS FOR VEHICLE TEST
NUMC = 0:                REM    NUMERATOR IN CALINE CORRELATION COEFFICIENT FOR ALL VEHICLE ON A
CYCLE
P1 = 6:                  REM    NUMBER OF ESTIMATED PARAMETERS FOR CALINE
P2 = 16:                 REM    NUMBER OF ESTIMATED PARAMETERS FOR EMFAC 7F
PREDFACT = 0:            REM    AVERAGE RATIO OF PREDICTED/ACTUAL SUMMED EMISSIONS
PRODC = 0:               REM    PRODUCT OF ACTUAL EMISSIONS AND CALINE PREDICTED EMISSIONS FOR
VEHICLE/CYCLE
PRODE = 0:               REM    PRODUCT OF ACTUAL EMISSIONS AND EMFAC 7F PREDICTED EMISSIONS
REPORTL = 1:             REM    REPORT LEVEL DESIRED FROM USER
RSQURE1 = 0:             REM    R-SQUARE VALUE FOR MULTIPLE RUN (CALINE)
RSQURE2 = 0:             REM    R-SQUARE VALUE FOR MULTIPLE RUN (CALINE)
RSQURE1ADJ = 0:          REM    ADJUSTED R-SQUARE VALUE FOR MULTIPLE RUN (CALINE)
RSQURE2ADJ = 0:          REM    ADJUSTED R-SQUARE VALUE FOR MULTIPLE RUN (CALINE)
SCF = 0:                 REM    SPEED CORRECTION FACTOR PRODUCED BY EMFAC 7F
SMODELl = 0:             REM    SQUARED PREDICTED (CALINE)MINUS AVERAGE EMISSIONS
SERRORl = 0:             REM    SQUARED ACTUAL (CALINE)MINUS PREDICTED EMISSIONS
```

```
STOTALl = 0:              REM     SQUARED ACTUAL (CALINE) MINUS AVERAGE EMISSIONS
SSMODELl = 0:             REM     SUM OF SMODELl FOR MULTIPLE RUN (CALINE)
SSERRORl = 0:             REM     SUM OF SERRORl FOR MULTIPLE RUN (CALINE)
SSTOTALl = 0:             REM     SUM OF STOTALl FOR MULTIPLE RUN (CALINE)
SMODEL2 = 0:              REM     SQUARED PREDICTED (EMFAC 7F) MINUS AVERAGE EMISSIONS
SERROR2 = 0:              REM     SQUARED ACTUAL (EMFAC 7F) MINUS PREDICTED EMISSIONS
STOTAL2 = 0:              REM     SQUARED ACTUAL (EMFAC 7F) MINUS AVERAGE EMISSIONS
SSMODEL2 = 0:             REM     SUM OF SMODELZ FOR MULTIPLE RUN
SSERROR2 = 0:             REM     SUM OF SERROR2 FOR MULTIPLE RUN
SSTOTAL2 = 0:             REM     SUM OF STOTAL2 FOR MULTIPLE RUN
SPEEDSUM = 0:             REM     USED FOR SUMMING AVERAGE SPEEDS OF EVENT
SUMPRODC = 0:             REM     SUM OF PRODC AND PRODE FOR ALL VEHICLES ON CYCLE
SUMEMISC = 0:             REM     SUM OF CALINE PREDICTED EMISSIONS FOR ALL VEHICLES ON A CYCLE
SUMEMISCSQ = 0:           REM     SUM OF SQUARED CALINE PREDICTED EMISSIONS FOR ALL VEHILCES ON A
CYCLE
TESTRESULT = 0:           REM     USER INPUT GRAM/MILE TEST RESULT FOR COMPARISON TEST
TOTCALEMISS = 0:          REM     TOTAL CALINE SUMMED EMISSIONS FOR CYCLE
TOTACTEMISS = 0:          REM     TOTAL ACTUAL SUMMED EMISSIONS FOR CYCLE
TOTEMFAC 7FEMISS = 0:        REM     TOTAL EMFAC 7F SUMMED EMISSIONS FOR CYCLE
VA1 = 0:                  REM     AVERAGE SPEED INDEPENDENT VARIABLE #1 €OR EMFAC 7F MODEL
VA2 = 0:                  REM     AVERAGE SPEED INDEPENDENT VARIABLE #2 FOR EMEAC 7F MODEL
VA3 = 0:                  REM     AVERAGE SPEED INDEPENDENT VARIABLE #3 FOR EMFAC 7F MODEL
VA4 = 0:                  REM     AVERAGE SPEED INDEPENDENT VARIABLE #4 €OR EMFAC 7F MODEL
VEHNUM = 0:               REM     VEHICLE IDENTIFICATION NUMBER (TESTING FACILITY SUPPLIED)

REDIM ACCAVGI(150):          REM     AVG ACCELERATION ARRAY FOR SUMMARY OUTPUT I=IDLE
REDIM ACCAVGA(150):          REM     AVG ACCELERATION ARRAY FOR SUMMARY OUTPUT A=ACCEL
REDIM ACCAVGC(150):          REM     AVG ACCELERATION ARRAY FOR SUMMARY OUTPUT C=CRUISE
REDIM ACCAVGD(150):          REM     AVG ACCELERATION ARRAY FOR SUMMARY OUTPUT D=DECEL
REDIM CHOICE$(20):           REM     HEADER TITLE FOR PRINTED AND FILE OUTPUT
REDIM CYCLENI(150):          REM     CYCLE LENGTH ARRAY FOR SUMMARY OUTPUT
REDIM CYCLENA(150):          REM     CYCLE LENGTH ARRAY FOR SUMMARY OUTPUT
REDIM CYCLENC(150):          REM     CYCLE LENGTH ARRAY FOR SUMMARY OUTPUT
REDIM CYCLEND(150):          REM     CYCLE LENGTH ARRAY FOR SUMMARY OUTPUT
REDIM EMISA(500):            REM     ACTUAL EMISSION ARRAY
REDIM EMISC(500):            REM     CALINE EMISSION ESTIMATE ARRAY
REDIM EMISE(500):            REM     EMFAC 7F EMISSION ESTIMATE ARRAY
REDIM ENDSPEEDI(150):        REM     ENDSPEED ARRAY FOR SUMMARY OUTPUT
REDIM ENDSPEEDA(150):        REM     ENDSPEED ARRAY FOR SUMMARY OUTPUT
REDIM ENDSPEEDC(150):        REM     ENDSPEED ARRAY FOR SUMMARY OUTPUT
REDIM ENDSPEEDD(150):        REM     ENDSPEED ARRAY FOR SUMMARY OUTPUT
REDIM EMISSI(150):           REM     CALINE EMISSION ESTIMATE FOR IDLE EVENTS
REDIM EMISSA(150):           REM     CALINE EMISSION ESTIMATE FOR ACCEL EVENTS
REDIM EMISSC(150):           REM     CALINE EMISSION ESTIMATE €OR CRUISE EVENTS
REDIM EMISSD(150):           REM     CALINE EMISSION ESTIMATE FOR DECEL EVENTS
REDIM PKEAVGI(150):          REM     AVG POSITIVE KINETIC ENERGY ARRAY FOR SUMMARY OUTPUT
REDIM PKEAVGA(150):          REM     AVG POSITIVE KINETIC ENERGY ARRAY FOR SUMMARY OUTPUT
REDIM PKEAVGC(150):          REM     AVG POSITIVE KINETIC ENERGY ARRAY FOR SUMMARY OUTPUT
REDIM PKEAVGD(150):          REM     AVG POSITIVE KINETIC ENERGY PRRAY FOR SUMMARY OUTPUT
REDIM PREVSPD(1000):         REM     DIMENSION PREVIOUS SPEED FOR LENGTH OF CYCLE
```

```
REDIM SPDAVGI(150):        REM    AVG SPEED ARRAY FOR SUMMARY OUTPUT
REDIM SPDAVGA(150):        REM    AVG SPEED ARRAY FOR SUMMARY OUTPUT
REDIM SPDAVGC(150):        REM    AVG SPEED ARRAY FOR SUMMARY OUTPUT
REDIM SPDAVGD(150):        REM    AVG SPEED ARRAY FOR SUMMARY OUTPUT
REDIM STARTSPEEDI(150):    REM    STARTSPEED ARRAY FOR SUMMARY OUTPUT
REDIM STARTSPEEDA(150):    REM    STARTSPEED ARRAY FOR SUMMARY OUTPUT
REDIM STARTSPEEDC(150):    REM    STARTSPEED ARRAY FOR SUMMARY OUTPUT
REDIM STARTSPEEDD(150):    REM    STARTSPEED ARRAY FOR SUMMARY OUTPUT

REM ____________________________________________________________________


REM *******************USER INPUT - OPENING MENUS ************************


CLS
PRINT "
PRINT "
PRINT "                                                              "
PRINT "          ---- UC DAVIS W I N E EMISSION ANALYSIS PROGRAM ----"
PRINT "                 By:  Simon Washington & Randall Guensler"
PRINT "                           Copyright 1993"
PRINT "
INPUT ; "Press any key to continue"; KEYPRESS
10
CLS
PRINT "                                                              "
PRINT "                                                              "
PRINT "                                                              "
PRINT "This is the main menu of the UC Davis CALINE4 Emission Assessment "
PRINT "Program.  Please choose the menu option you would like."
PRINT "
PRINT "  1 - Receive detailed description of program capabilities"
PRINT "  2 - Break down a test cycle into sequential steady-state modes."
PRINT "  3 - Summary of emission estimates by mode for single vehicle."
PRINT "  4 - Summary of emissions results for all tested vehicles on a cycle."
PRINT "  5 - Summary of model performance for all vehicles on all cycles."
PRINT "                                                               "
INPUT ; "Please input menu choice.  "; MENU
PRINT "
CLS
IF MENU > 2 THEN
    PRINT "Would you like to use individual vehicle test results for BAG2 "
    PRINT "and IDLE, or would you like to use averages?"
    PRINT "1 = individual (theoretical),2 = averages (CALINE & EMFAC 7F algorythms)"
    INPUT ; ANSWER
    END IF
IF MENU < 1 OR MENU > 5 THEN GOTO 10
IF MENU > 4 THEN
```

```
    PRINT "This menu selection will take about 5 hours.  Would you like"
    INPUT ; "to go to the main menu selection again? (Y/N) "; ANSWERS
    IF ANSWER$ = "Y" OR ANSWER$ = "YES" OR ANSWER$ = "y" OR ANSWER$ = "yes" THEN GOTO 10
END IF
IF MENU > 1 THEN GOTO 20



REM    --------------------DETAILED DESCRIPTION OF PROGRAM--------------
CLS
PRINT "
PRINT "
PRINT "
PRINT "This program was written as a research tool by Simon Washington and"
PRINT "Randall Guensler.  The primary purpose of the program is to simulate"
PRINT "the internal workings of the CALINE4 line source dispersion model "
PRINT "in order to assess its ability to predict emissions.  Of concern is"
PRINT "the ability of CALINE4 to predict emissions from cycles other than the"
PRINT "Federal Test Procedure BAG2 result - the cycle on which it was"
PRINT "'calibrated'.  Consequently, this program predicts modal emissions from"
PRINT "various test cycles based upon the CALINE4 model.  There are several "
PRINT "different files that can be generated from this program."
PRINT "                                                              "
PRINT "The first is a sequential report describing the modal breakdown of "
PRINT "various test cycles.  This may be useful for comparing to the actual "
PRINT "speed-time trace of the chosen test cycle.  It should be noted that the "
PRINT "cutpoint chosen to discriminate between steady-state modes has a "
PRINT "significant effect on the discretization of the test cycles.  A high "
PRINT "cutpoint of around 1.00 mph/sec results in fewer steady-state modes,"
PRINT "while a low cutpoint of around 0.1 mph/sec results in many steady-state"
PRINT "modes.  You can experiment with the cutpoint feature in the program."
PRINT "
INPUT ; "Please press any key to continue."; CONT
CLS
PRINT "                                                                   "
PRINT "                                                                   "
PRINT "                                                                   "
PRINT "The second type of report is a detailed summary report of idle, "
PRINT "acceleration, deceleration, and cruise modes.  This report includes"
PRINT "information about CALINE4's prediction of emissions by steady-state''
PRINT "mode for a given cycle.  It also includes summary information about "
PRINT "average speeds, average accelerations, etc. about each steady-state''
PRINT "mode.  CALINE4's emission prediction can be compared to the actual"
PRINT "BAG2 result for the given cycle."
PRINT "
PRINT "The final report gives only information about emissions estimates "
PRINT "based on both the CALINE4 model and based upon the actual BAG2 results."
PRINT "This final report is useful for doing many runs with many vehicles and "
PRINT "cycles."
INPUT ; "Please press any key to continue."; CONT
```

```
CLS
GOTO 10

REM     -------------DESCRIPTION/SELECTION OF CYCLES---------------
20
CLS
PRINT "
PRINT "
PRINT "
IF MENU <> 5 THEN PRINT "The following test cycles can be analyzed by this program."
PRINT "
PRINT , " 1 - FEDERAL TEST PROCEDURE, BAG 1"
CHOICES(1) - "FEDERAL TEST PROCEDURE, BAG 1": REM   HEADER FOR OUTPUT
PRINT , " 2 - FEDERAL TEST PROCEDURE,, BAG 2"
CHOICE$(2) = "FEDERAL TEST PROCEDURE, BAG 2"
PRINT , " 3 - FEDERAL TEST PROCEDURE, BAG 3"
CHOICE$ (3) - "FEDERAL TEST PROCEDURE, BAG 3"
PRINT , " 4 - HIGHWAY FUEL ECONOMY TEST"
CHOICE$(4) = "HIGHWAY FUEL ECONOMY TEST"
PRINT , " 5 - HIGH SPEED TEST CYCLE # 1"
CHOICE$(5) = "HIGH SPEED TEST CYCLE # 1"
PRINT , " 6 - HIGH SPEED TEST CYCLE # 2"
CHOICE$(6) = "HIGH SPEED TEST CYCLE # 2"
PRINT , " 7 - HIGH SPEED TEST CYCLE # 3"
CHOICE$(7) = "HIGH SPEED TEST CYCLE # 3"
PRINT , " 8 - HIGH SPEED TEST CYCLE # 4"
CHOICE$(8) = "HIGH SPEED TEST CYCLE # 4"
PRINT , " 9 - LOW SPEED TEST CYCLE # 1"
CHOICE$(9) = "LOW SPEED TEST CYCLE # 1"
PRINT , "10 - LOW SPEED TEST CYCLE #2"
CHOICE$(10) = "LOW SPEED TEST CYCLE # 2"
PRINT , "11 - LOW SPEED TEST CYCLE #3"
CHOICE$ (11)= "LOW SPEED TEST CYCLE # 3"
PRINT , "12 - NEW YORK CITY CYCLE"
CHOICE$(12) = "NEW YORK CITY CYCLE"
PRINT , "13 - SPEED CORRECTION FACTOR CYCLE 12"
CHOICE$(13) = "SPEED CORRECTION FACTOR CYCLE 12"
PRINT , "14 - SPEED CORRECTION FACTOR CYCLE 36"
CHOICE$(14) = "SPEED CORRECTION FACTOR CYCLE 36"

REM --------------------REQUEST USER INPUTS----------------------------------

IF MENU = 5 THEN
    OPEN "C:\UCDCAL\EMISS.OUT$" FOR OUTPUT AS #10
    GOTO 35
END IF
INPUT ; "Please input the number of the cycle you would like to analyze.  "; CYCLNUM
IF CYCLNUM >= 15 OR CYCLNUM <= 0 THEN GOTO 20
IF MENU = 2 THEN GOTO 30
IF MENU = 4 THEN GOTO 40
```

```
PRINT "
IF ANSWER = 1 THEN
    PRINT "The program utilizes the FTP-BAG2 emission rate to perform calculations."
    PRINT ; "Please input the FTP-BAG2 emission rate in grams/mile.  "
    INPUT ; "FTP-BAG2 EMISSION RATE = "; BAG2RES
END IF
PRINT "
IF ANSWER = 1 THEN
    PRINT "The program also uses the idle emission factor provided in EMFAC 7F output."
    PRINT ; "Please input the idle emission factor in grams/hour.   "
    INPUT ; "IDLE EMISSION FACTOR FOR  = "; IDLEFACT1
END IF
PRINT "
PRINT "In addition, the program needs the gram/mile test result for the chosen cycle."
PRINT "Please input the test result in grams/mile.  "
INPUT ; "COMPARISON TEST RESULT = "; TESTRESULT
PRINT "                                                              "
30
PRINT "As discussed earlier, the cutrate is used to determine the break between"
PRINT "steady-state modal events.  Please input the cutrate in mph/sec. "
INPUT ; "CUTRATE = "; CUTRATE
PRINT "
CLS
IF MENU <> 5 THEN GOTO 40
REM ________________________________________________________________

35
REM ***********************LOOP FOR MENU CHOICE 5 ***********************

FOR CYCLNUM = 1 TO 14
    IF CYCLNUM = 1 THEN
        CLS
        PRINT "                                               "
        PRINT "                                               "
        PRINT "                                               "
        PRINT "I am now working really hard!!!"
        PRINT "Start                          Half-Way                          Finish"
    END IF
    FOR CUTRATE = .6 TO .7 STEP .1
        PRINT "-";

REM ________________________________________________________________



40
REM ***********************OPEN INPUT FILES*******************************

 IF CYCLNUM = 1 THEN
    IF MENU > 3 THEN OPEN "C:\UCDCAL\FTPB1E.DAT$" FOR INPUT AS #5
```

```
    ENDLOOP2 = 464
    AVGCYCSPD = 25.6
    IDLEAVE = 151.78
    BAG2AVE = 11.08
ELSEIF CYCLNUM = 2 THEN
    IF MENU > 3 THEN OPEN "C:\UCDCAL\FTPB2E.DAT$" FOR INPUT AS #5
    ENDLOOP2 = 464
    AVGCYCSPD = 16
    IDLEAVE = 151.78
    BAG2AVE = 11.08
ELSEIF CYCLNUM = 3 THEN
    IF MENU > 3 THEN OPEN "C:\UCDCAL\FTPB3E.DAT$" FOR INPUT AS #5
    ENDLOOP2 = 464
    AVGCYCSPD = 25.6
    IDLEAVE = 151.78
    BAG2AVE = 11.08
ELSEIF CYCLNUM = 4 THEN
    IF MENU > 3 THEN OPEN "C:\UCDCAL\HFETE.DAT$" FOR INPUT AS #5
    ENDLOOP2 = 464
    AVGCYCSPD = 48.3
    IDLEAVE = 151.78
    BAG2AVE = 11.08
ELSEIF CYCLNUM = 5 THEN
    IF MENU > 3 THEN OPEN "C:\UCDCAL\HS1E.DAT$" FOR INPUT AS #5
    ENDLOOP2 = 25
    AVGCYCSPD = 45.1
    IDLEAVE = 0
    BAG2AVE = 2.94
ELSEIF CYCLNUM = 6 THEN
    IF MENU > 3 THEN OPEN "C:\UCDCAL\HS2E.DAT$" FOR INPUT AS #5
    ENDLOOP2 = 25
    AVGCYCSPD = 51
    IDLEAVE = 0
    BAG2AVE = 2.94
ELSEIF CYCLNUM = 7 THEN
    IF MENU > 3 THEN OPEN "C:\UCDCAL\HS3E.DAT$" FOR INPUT AS #5
    ENDLOOP2 = 69
    AVGCYCSPD = 57.8
    IDLEAVE = 0
    BAG2AVE = 2.35
ELSEIF CYCLNUM = 8 THEN
    IF MENU > 3 THEN OPEN "C:\UCDCAL\HS4E.DAT$" FOR INPUT AS #5
    ENDLOOP2 = 69
    AVGCYCSPD = 64.4
    IDLEAVE = 0
    BAG2AVE = 2.35
ELSEIF CYCLNUM = 9 THEN
    IF MENU > 3 THEN OPEN "C:\UCDCAL\LS1E.DAT$" FOR INPUT AS #5
    ENDLOOP2 = 236
    AVGCYCSPD = 4.02
```

```
    IDLEAVE = 76.47
    BAG2AVE = 8.4
ELSEIF CYCLNUM = 10 THEN
    IF MENU > 3 THEN OPEN "C:\UCDCAL\LS2E.DAT$" FOR INPUT AS #5
    ENDLOOP2 = 236
    AVGCYCSPD = 3.64
    IDLEAVE = 76.47
    BAG2AVE = 8.4
ELSEIF CYCLNUM = 11 THEN
    IF MENU > 3 THEN OPEN "C:\UCDCAL\LS3E.DAT$" FOR INPUT AS #5
    ENDLOOP2 = 236
    AVGCYCSPD = 2.45
    IDLEAVE = 76.47
    BAG2AVE = 8.4
ELSEIF CYCLNUM = 12 THEN
    IF MENU > 3 THEN OPEN "C:\UCDCAL\NYCCE.DAT$" FOR INPUT AS #5
    ENDLOOP2 = 464
    AVGCYCSPD = 7.1
    IDLEAVE = 151.78
    BAG2AVE = 11.08
ELSEIF CYCLNUM = 13 THEN
    IF MENU > 3 THEN OPEN "C:\UCDCAL\SC12E.DAT$" FOR INPUT AS #5
    ENDLOOP2 = 464
    AVGCYCSPD = 12.1
    IDLEAVE = 151.78
    BAG2AVE = 11.08
ELSEIF CYCLNUM = 14 THEN
    IF MENU > 3 THEN OPEN "C:\UCDCAL\SC36E.DAT$" FOR INPUT AS #5
    ENDLOOP2 = 464
    AVGCYCSPD = 35.9
    IDLEAVE = 151.78
    BAG2AVE = 11.08
ELSEIF CYCLNUM >= 15 OR CYCLNUM <= 0 THEN
    GOTO 10
END IF

IF MENU = 2 THEN
    OPEN "C:\UCDCAL\REPORT1.OUT$" FOR OUTPUT AS #2
    WIDTH #2, 132
END IF

IF MENU = 3 THEN
    OPEN "C:\UCDCAL\REPORT2.OUT$" FOR OUTPUT AS #3
    WIDTH #3, 132
END IF

IF MENU = 4 THEN
    OPEN "C:\UCDCAL\REPORT3.OUT$" FOR OUTPUT AS #4
END IF
```

```
  IF MENU = 5 AND CYCLNUM = 1 AND CUTRATE = .6 THEN
     OPEN "C:\UCDCAL\REPORT4.OUT$" FOR OUTPUT AS #6
     OPEN "C:\UCDCAL\REPORT5.OUT$" FOR OUTPUT AS #7
  END IF

  IF MENU < 4 THEN
     ENDLOOPZ = 1
  END IF
  IF MENU <> 5 THEN OPEN "C:\UCDCAL\EMISS.OUT$" FOR OUTPUT AS #10                •

REM ____________________________________________________________________________


REM********LOOP FOR READING USER CHOSEN EMISSION FILES (CYCLE)*************

FOR K = 1 TO ENDLOOP2
    IF MENU = 4 THEN INPUT #5, TESTRESULT, BAGPRES, IDLEFACTl, VEHNUM, MODYR, CID, NUMCYLN, FINJ
REM --------- PRINT PROGRESS REPORT TO SCREEN ----------
    IF ENDLOOP2 >= SO THEN
        M = ENDLOOP2 / 50
        IF K = INT(M * O) AND MENU <> 5 THEN
            PRINT "-";
            O - O + 1
        END IF
    END IF
   IF ENDLOOP2 < 50 AND MENU = 4 AND K <> 1 THEN
        PRINT "--";
   END IF
REM ---------- END OF PROGRESS REPORT -------------------

   IF MENU = 5 THEN INPUT #5, TESTRESULT, BAG2RES, IDLEFACTl, VEHNUM, MODYR, CID, NUMCYLN, FINJ
   IF MENU = 4 AND K = 1 THEN
        PRINT "
        INPUT "Please enter the modal cutrate for this analysis "; CUTRATE
        CLS
        PRINT "                                                    "
        PRINT "                                                    "
        PRINT "
        PRINT "I am now working really hard to do the calculations!"
        PRINT "Start                 Half-Way               Finish"
    END IF


REM************************OPEN INPUT FILES FOR INNER LOOP*****************

 IF CYCLNUM = 1 THEN
    OPEN "C:\UCDCAL\FTPB1.DAT$" FOR INPUT AS #1
    ENDLOOP = 505
 ELSEIF CYCLNUM = 2 THEN
```

```
    OPEN "C:\UCDCAL\FTPB2.DAT$" FOR INPUT AS #1
    ENDLOOP = 866
  ELSEIF CYCLNUM = 3 THEN
    OPEN "C:\UCDCAL\FTPB3.DAT$" FOR INPUT AS #1
    ENDLOOP = 505
  ELSEIF CYCLNUM = 4 THEN
    OPEN "C:\UCDCAL\HFET.DAT$" FOR INPUT AS #1
    ENDLOOP = 765
  ELSEIF CYCLNUM = 5 THEN
    OPEN "C:\UCDCAL\HS1.DAT$" FOR INPUT AS #1
    ENDLOOP = 474
  ELSEIF CYCLNUM = 6 THEN
    OPEN "C:\UCDCAL\HS2.DATS" FOR INPUT AS #1
    ENDLOOP = 480
  ELSEIF CYCLNUM = 7 THEN
    OPEN "C:\UCDCAL\HS3.DAT$" FOR INPUT AS #1
    ENDLOOP = 486
  ELSEIF CYCLNUM = 8 THEN
    OPEN "C:\UCDCAL\HS4.DAT$" FOR INPUT AS #1
    ENDLOOP = 492
  ELSEIF CYCLNUM = 9 THEN
    OPEN "C:\UCDCAL\LS1.DAT$" FOR INPUT AS #1
    ENDLOOP = 624
  ELSEIF CYCLNUM = 10 THEN
    OPEN "C:\UCDCAL\LS2.DAT$" FOR INPUT AS #1
    ENDLOOP = 637
  ELSEIF CYCLNUM = 11 THEN
    OPEN "C:\UCDCAL\LS3.DAT$" FOR INPUT AS #1
    ENDLOOP = 616
  ELSEIF CYCLNUM = 12 THEN
    OPEN "C:\UCDCAL\NYCC.DAT$" FOR INPUT AS #1
    ENDLOOP = 598
  ELSEIF CYCLNUM = 13 THEN
    OPEN "C:\UCDCAL\SC12.DATS" FOR INPUT AS #1
    ENDLOOP = 349
  ELSEIF CYCLNUM = 14 THEN
    OPEN "C:\UCDCAL\SC36.DAT$" FOR INPUT AS #1
    ENDLOOP = 996
  END IF

REM ________________________________________________________________


REM*******************PROGRAM TO BREAKDOWN STEADY STATE MODES**************
REM**********************************************************************

FOR COUNT = 2 TO (ENDLOOP + 1) :      REM   COUNTER FOR CYCLE LENGTH (SECONDS +1)
      INPUT #1, TIME, SPEED:          REM   INPUT FROM FILE, SECONDS AND MPH
      I = I + 1:                      REM   COUNTER FOR STEADY-STATE CYCLE LENGTH
      PREVSPD(COUNT) = SPEED:         REM   ARRAY CONTAINING SPEED INFORMATION
```

```
        ACCEL = SPEED - LASTSPD:        REM     COMPUTE ACCELERATION RATE
        IF ACCEL > CUTRATE THEN CRIT = 1:               REM     DECISION FOR TYPE OF STEADY-
        IF ACCEL < -(CUTRATE) THEN CRIT = -1:           REM     STATE MODE, ACCEL=1, CRUISE=
        IF ACCEL <= CUTRATE AND ACCEL >= -(CUTRATE) THEN CRIT = 0:      REM 0, DECEL = -1

REM     INSTRUCTIONS FOR CONTINUING STEADY-STATE MODAL EVENT LOOP
90    IF CRIT = LASTCRIT AND COUNT <> (ENDLOOP + 1) THEN
        SPEEDSUM = SPEED + LASTSSUM
        LASTSPD = SPEED:        REM     COMPUTE SPEED AVERAGE FOR EVENT
        LASTSSUM = SPEEDSUM

REM     INSTRUCTIONS FOR ENDING STEADY-STATE MODAL EVENT LOOP
      ELSEIF CRIT <> LASTCRIT OR COUNT = (ENDLOOP + 1) THEN
        AVGSPEED = (SPEEDSUM + PREVSPD(COUNT - I - 1)) / (I + 1)
        AVGACCEL = (PREVSPD(COUNT - 1) - PREVSPD(COUNT - I - 1)) / I
        AVGPKE = AVGSPEED * AVGACCEL
        AVGACCEL = FIX(AVGACCEL * 100) / 100:   REM     SET SIGN. DIGITS
        AVGSPEED = FIX(AVGSPEED * 100) / 100
        AVGPKE = FIX(AVGPKE * 100) / 100


 GOSUB 100:         REM     CALCULATE STEADY-STATE MODAL EVENTS
 GOSUB 200:         REM     CALCULATE CALINE EMISSION ESTIMATES

    IF MENU = 2 THEN GOSUB 1000: REM     PRINT SEQUENTIAL RESULTS

 GOSUB 300:         REM     RE-INITIALIZE MODAL VARIABLES

    END IF

  NEXT COUNT:       REM     NEXT TIME AND SPEED READ

 GOSUB 400:         REM     COMPUTE EMISSION TOTALS FOR ACTUAL, EMFAC 7F, AND CALINE
 GOSUB 450:         REM     COMPUTE ANOVA RESULTS FOR REPORT 3
 GOSUB 475:         REM     WRITE PREDICTED & OBSERVED TO OUTPUT FILE

    IF MENU = 3 THEN GOSUB 2000: REM     PRINT REPORT2
    IF MENU = 4 THEN GOSUB 3000: REM     PRINT REPORT3

 CLOSE #1
 CLOSE #2
 CLOSE #3

 GOSUB 500:         REM     RE-INITIALIZE EMISSION VARIABLES

 NEXT K:            REM     READ NEXT VEHICLE RESULTS

 CLOSE #4
 CLOSE #5
```

```
   IF MENU = 5 THEN GOSUB 4000:  REM      PRINT REPORT4

GOSUB 600:         REM     RE-INITIALIZE ALL VARIABLES

NEXT CUTRATE
NEXT CYCLNUM

CLOSE #6
CLOSE #7
CLOSE #10

   PRINT "
   IF MENU = 2 THEN PRINT "The output is saved as c:\ucdcal\report1.out"
   IF MENU = 3 THEN PRINT "The output is saved as c:\ucdcal\report2.out"
   IF MENU = 4 THEN PRINT "The output Is saved as c:\ucdcal\report3.out"
   IF MENU = 5 THEN PRINT "The output is saved as c:\ucdcal\report4.out"
   IF MENU = 5 THEN PRINT "and report5.out"
   PRINT "                                                 "

END
REM ______________________________________________________________________



REM******** CALCULATE STEADY-STATE MODAL VARIABLES SUBROUTINE *************
100
REM __--__- CALCULATE ACCELERATION MODAL VARIABLES---------
        IF LASTCRIT = 1 THEN
              ACCCNT = ACCCNT + 1
              ACCAVGA(ACCCNT) = AVGACCEL
              SPDAVGA(ACCCNT) = AVGSPEED
              PKEAVGA(ACCCNT) = AVGPKE
              CYCLENA(ACCCNT) = I
              STARTSPEEDA(ACCCNT) = PREVSPD(COUNT - I - 1)
              ENDSPEEDA(ACCCNT) = PREVSPD(COUNT - 1)
              CYCLENTOTA = CYCLENTOTA + CYCLENA(ACCCNT)

REM -------CALCULATE DECELERATION MODAL VARIABLES ----------
        ELSEIF LASTCRIT = -1 THEN
              DECELCNT = DECELCNT + 1
              ACCAVGD(DECELCNT) = AVGACCEL
              SPDAVGD(DECELCNT) = AVGSPEED
              PKEAVGD( DECELCNT! = AVGPKE
              CYCLEND(DECELCNT) = I
              STARTSPEEDD(DECELCNT) = PREVSPD(COUNT - I - il
              ENDSPEEDD(DECELCNT) = PREVSPD(COUNT - 1)
              CYCLENTOTD = CYCLENTOTD + CYCLEND(DECELCNT)

REM ------------ CALCULATE IDLE MODAL VARIABLES -----------
         ELSEIF LASTCRIT = 0 AND AVGSPEED = 0 THEN
```

```
                IDLECNT = IDLECNT + 1
                ACCAVGI(IDLECNT) = AVGACCEL
                SPDAVGI(IDLECNT)= AVGSPEED
                PKEAVGI(IDLECNT) = AVGPKE
                CYCLENI(IDLECNT) = I
                STARTSPEEDI(IDLECNT) = PREVSPD(COUNT - I - 1)
                ENDSPEEDI(IDLECNT) = PREVSPD(COUNT - 1)
                CYCLENTOTI = CYCLENTOTI t CYCLENI(IDLECNT)


REM ---_------ CALCULATE CRUISE MODAL VARIABLES -----------
           ELSEIF LASTCRIT = 0 AND AVGSPEED <> 0 THEN
                CRUZCNT = CRUZCNT t 1
                ACCAVGC(CRUZCNT) = AVGACCEL
                SPDAVGC(CRUZCNT) = AVGSPEED
                PKEAVGC(CRUZCNT) = AVGPKE
                CYCLENC(CRUZCNT) = I
                STARTSPEEDC(CRUZCNT) = PREVSPD(COUNT - I - 11
                ENDSPEEDC(CRUZCNT) = PREVSPD(COUNT - 1)
                CYCLENTOTC = CYCLENTOTC + CYCLENC(CRUZCNT)

           END IF
    RETURN
REM ______________________________________________________________________



REM ***************** CALINE EMISSION ESTIMATES SUBROUTINE*****************
REM ************************************************************************
200
IF ANSWER = 1 THEN
    BAG2 = BAG2RES • 16 / 60
    IDLEFACT2 = IDLEFACT1 / 3600
END IF
IF ANSWER = 2 THEN
    BAG2 = BAG2AVE * 16 / 60
    IDLEFACT2 = IDLEAVE / 3600
END IF

REM ------------- CALCULATE ACCEL EMISSIONS ---------------
 IF LASTCRIT = 1 THEN
    IF PREVSPD(COUNT - I - 1) = 0 AND PREVSPD(COUNT - I) <= 45 THEN
        COEFFl = .75
        COEFFZ = .0454
    ELSE
        COEFFl = .027
        COEFF2 = .098
    END IF
        EMISSA(ACCCNT) = (BAG2 * COEFFl * EXP(COEFF2 * AVGPKE)) * I / 60
```

```
        EMISSATOT = EMISSATOT + EMISSA(ACCCNT)


REM -------------- CALCULATE DECEL EMISSIONS --------------
 ELSEIF LASTCRIT = -1 THEN
        EMISSD(DECELCNT) = IDLEFACT2 * 1.5 * I
        EMISSDTOT = EMISSDTOT + EMISSD(DECELCNT)


REM -------------- CALCULATE IDLE EMISSIONS --------------
 ELSEIF LASTCRIT = 0 AND AVGSPEED = 0 THEN
        EMISSI(IDLECNT) = IDLEFACT2 * I
        EMISSITOT = EMISSITOT + EMISSI(IDLECNT)


REM ---------------- CALCULATE CRUISE EMISSIONS ----------
 ELSEIF LASTCRIT = 0 AND AVGSPEED <> 0 THEN
    EMISSC(CRUZCNT) = BAG2 * (.494 + .000227 • AVGSPEED ^ 2) * I / 60
    EMISSCTOT = EMISSCTOT + EMISSC(CRUZCNT)
 END IF
RETURN
REM ____________________________________________________________________



REM ************* RE-INITIALIZE MODAL VARIABLES SUBROUTINE ***************
REM ********************************************************************
300
        AVGSPEED = 0
        AVGACCEL = 0
        LASTSPD = 0:
        SPEEDSUM = 0
        LASTSSUM = 0
        I = 0
        J = J + 1
        LASTCRIT = CRIT
        SPEEDSUM = SPEED + LASTSSUM
        LASTSPD = SPEED
        LASTSSUM = SPEEDSUM

REM --------------------------------------------------------------------



REM ********** COMPUTE EMISSION TOTALS SUBROUTINE ***********************
REM ********************************************************************
400

REM ------------- COMPUTE ACTUAL EMISSIONS FROM VEHICLES-----------------
EMISSACT = (TESTRESULT / 3600) * AVGCYCSPD * (CYCLENTOTC + CYCLENTOTA t CYCLENTOTD + CYCLENTOTI)
```

```
CYCLENTOT = CYCLENTOTI + CYCLENTOTA + CYCLENTOTC t CYCLENTOTD

REM ------------- COMPUTE ESTIMATED EMISSIONS FROM CALINE ----------------
EMISSCAL = EMISSDTOT + EMISSATOT + EMISSITOT t EMISSCTOT


REM --------------- COMPUTE ESTIMATED EMISSIONS FROM EMFAC 7F ----------------
REM      TECH GROUP 1
IF FINJ <> 1 AND MODYR < 86 THEN
    COEF1 = -.0374742678#
    COEF2 = .0040238362#
    COEF3 = -.0002407205#
    COEF4 = .0000038709#

REM      TECH GROUP2
ELSEIF FINJ = 1 AND MODYR < 86 THEN
    COEF1 = -.0652385244#
    COEF2 = -00157646921
    COEF3 = -.0000189154#
    COEF4 = .0000003058#

REM      TECH GROUP 3
ELSEIF FINJ <> 1 AND MODYR >= 86 THEN
    COEF1 = -.0399582631#
    COEF2 = .0030499479#
    COEF3 = -.0001657118#
    COEF4 = .0000027396#

REM      TECH GROUP 4
ELSEIF FINJ = 1 AND MODYR >= 86 THEN
    COEF1 = -.062119254#
    COEF2 = .0016933084#
    COEF3 = -.0000288896#
    COEF4 = .0000004345#
END IF

VA1 = (AVGCYCSPD - 16)
VA2 = (AVGCYCSPD - 16) ^ 2
VA3 = (AVGCYCSPD - 16) ^ 3
VA4 = (AVGCYCSPD - 16) ^ 4

IF ANSWER = 2 THEN BAG2RES = BAG2AVE

SCF = EXP((COEF1 * VA1) + (COEF2 * VA2) + (COEF3 * VA3) + (COEF4 * VA4))
EMISSEMFAC7F = SCF * BAG2RES * ENDLOOP * AVGCYCSPD / (3600)

RETURN
REM -----------------------------------------------------------------------
```

```
REM *********** STATISTICAL RESULTS SUBROUTINE **************************
REM ********************************************************************
450
P1 = 6
P2 = 16

TOTCALEMISS = TOTCALEMISS + EMISSCAL
TOTACTEMISS = TOTACTEMISS + EMISSACT
TOTEMFAC7FEMISS = TOTEMFAC7FEMISS + EMISSEMFAC7F

IF MENU > 3 THEN
EMISA(K) = EMISSACT
EMISC(K) = EMISSCAL
EMISE(K) = EMISSEMFAC7F

REM: --- COMPUTE MEAN EMISSION RATES --------

    IF K = ENDLOOP2 THEN
        MEANEMISSC = TOTCALEMISS / ENDLOOP2
        MEANEMISSA = TOTACTEMISS / ENDLOOP2
        MEANEMISSE = TOTEMFAC7FEMISS / ENDLOOP2

        MEANDIFF1 = MEANEMISSC - MEANEMISSA
        MEANDIFF2 = MEANEMISSE - MEANEMISSA


        FOR L = 1 TO ENDLOOP2
            REM: ---- COMPUTE SUM OF SQUARES FOR W I N E ----
            SMODEL1 = (EMISC(L) - MEANEMISSA) ^ 2
            SERROR1 = (EMISA(L) - EMISC(L)) ^ 2

            SSMODEL1 = SSMODEL1 + SMODEL1
            SSERROR1 = SSERROR1 + SERROR1


            REM: ---- COMPUTE SUM OF SQUARES €OR EMFAC 7F ----
            SMODEL2 = (EMISE(L) - MEANEMISSA) ^ 2
            SERROR2 = (EMISA(L) - EMISE(L)) ^ 2

            SSMODEL2 = SSMODEL2 + SMODEL2
            SSERROR2 = SSERROR2 + SERROR2

            REM: ---- COMPUTE CORRELATION COEFFICIENTS ----

            PRODC = EMISC(L) * EMISA(L)
            PRODE = EMISE(L) * EMISA(L)

            SUMPRODC = SUMPRODC + PRODC
            SUMPRODE = SUMPRODE t PRODE
```

```
            SUMEMISC = SUMEMISC + EMISC(L)
            SUMEMISE = SUMEMISE + EMISE(L)
            SUMEMISA = SUMEMISA + EMISA(L)

            EMISCSQ = EMISC(L) ^ 2
            EMISESQ = EMISE(L) ^ 2
            EMISASQ = EMISA(L) ^ 2

            SUMEMISCSQ = SUMEMISCSQ + EMISCSQ
            SUMEMISESQ = SUMEMISESQ + EMISESQ
            SUMEMISASQ = SUMEMISASQ + EMISASQ

          NEXT L

REM ------ COMPUTE SUM OF SQUARES TOTALS -----

    SSTOTALl = SSERRORl + SSMODELl
    SSTOTAL2 = SSERROR2 + SSMODEL2

    RSQUAREl = SSMODELl / SSTOTAL1 * 100
    RSQUARE2 = SSMODEL2 / SSTOTALP * 100

    RSQUARElADJ = (1- (ENDLOOP2 - 1) / (ENDLOOP2 - P1) * SSERRORl / SSTOTAL1) * 100
    RSQUARE2ADJ = (1 - (ENDLOOPZ - 1) / (ENDLOOP2 - P2) * SSERRORE / SSTOTALP) * 100

    IF RSQUARElADJ < 0 THEN RSQUARElADJ = 0
    IF RSQUARE2ADJ < 0 THEN RSQUARE2ADJ = 0

REM ------ COMPUTE CORRELATION COEFFICIENTS ------
    IF ANSWER = 1 THEN NUMC = (ENDLOOP2) * SUMPRODC - SUMEMISC * SUMEMISA
    IF ANSWER = 2 AND CYCLNUM = 2 THEN GOTO 452
    NUME = (ENDLOOP2) * SUMPRODE - SUMEMISE * SUMEMISA


    IF ANSWER = 1 THEN DEN1C = ((ENDLOOP2) * (SUMEMISCSQ)- (SUMEMISC)^ 2) ^ .5

    DEN1E = ((ENDLOOP2) * (SUMEMISESQ)- (SUMEMISE)^ 2) ^ .5

    DEN2 = ((ENDLOOP2) * (SUMEMISASQ)- (SUMEMISA) ^ 2) ^ .5

    IF ANSWER = 1 THEN CORRC = NUMC / (DEN1C * DEN2)
    IF ANSWER = 2 THEN CORRC = 0!
    CORRE = NUME / (DEN1E * DEN2)
452 IF ANSWER = 2 AND CYCLNUM = 2 THEN CORRE = 0!



REM ------ COMPUTE MEAN SQUARED PREDICTION ERROR -----

    MSPEC = SSERRORl / ENDLOOP2
```

```
    MSPEE = SSERROR2 / ENDLOOP2

   END IF
END IF



RETURN
REM ----------------------------------------------------------------------


REM ************ WRITE PREDICTED AND OBSERVED TO OUTPUT FILE *************
REM ***********************************************************************
475
WRITE #10, EMISSACT, EMISSCAL, EMISSEMFAC 7F
RETURN
REM ----------------------------------------------------------------------



REM ************ RE-INITIALIZE EMISSION VARIABLES SUBROUTINE *************
REM ***********************************************************************
500
        ACCCNT = 0:
        DECELCNT = 0:
        IDLECNT = 0
        CRUZCNT = 0
        EMISSCAL = 0
        EMISSACT = 0
        EMISSEMFAC 7F = 0
        EMISSDTOT = 0
        EMISSATOT = 0
        EMISSCTOT = 0
        EMISSITOT = 0
        CYCLENTOT = 0
        CYCLENTOTA = 0
        CYCLENTOTC = 0
        CYCLENTOTD = 0
        CYCLENTOTI = 0
RETURN
REM ----------------------------------------------------------------------

REM ******** INITIALIZE VARIABLES FOR OUTERLOOP SUBROUTINE ***************
600
ACCCNT = 0:
AVGSPEED = 0:
AVGCYCSPD = 0:
AVGACCEL = 0:
BAG2 = 0:
BAG2RES = 0:
```

```
CID = 0:
CRIT = 0:
COUNT = 1:
COEFFl = 0:
COEFFZ = 0:
COEFl = 0:
COEF2 = 0:
COEF3 = 0:
COEF4 = 0:
CRUZCNT = 0:
CYCLENTOT = 0:
CYCLENTOTI = 0:
CYCLENTOTA = 0:
CYCLENTOTC = 0:
CYCLENTOTD = 0:
DECELCNT = 0:
ENDLOOP = 0:
EMISSCAL = 0:
EMISSACT = 0:
EMISSENFAC = 0:
EMISSACTl = 0:
EMISSACT2 = 0:
EMISSITOT = 0:
EMISSCTOT = 0:
EMISSATOT = 0:
EMISSDTOT = 0:
EMISSTOT = 0:
FINJ = 0:
IDLECNT = 0:
IDLEFACT1 = 0:
IDLEFACT2 = 0:
LASTSPD = 0:
LASTSSUM = 0:
LASTCRIT = 0:
MODYR = 0:
MEANDIFF1 = 0:
MEANDIFF2 = 0:
MEANEMISSA = 0:
MEANEMISSC = 0:
MEANEMISSE = 0:
NUMCYCLE = 0:
P1 = 4:
P2 = 16:
PREDFACT = 0:
REPORTL = 1:
RSQUAREl = 0:
RSQUARE2 = 0:
RSQUARElADJ = 0:
RSQUAREZADJ = 0:
SCF = 0:
```

```
SMODEL1 = 0:
SERROR1 = 0:
STOTAL1 = 0:
SSMODEL1 = 0:
SSERROR1 = 0:
SSTOTAL1 = 0:
SMODEL2 = 0:
SERRORP = 0:
STOTAL2 = 0:
SSMODELP = 0:
SSERROR2 = 0:
SSTOTAL2 = 0:
SPEEDSUM = 0:
SUMPRODC = 0:
SUMPRODE = 0:
SUMEMISE = 0:
SUMEMISC = 0:
SUMEMISA = 0:
SUMEMISCSQ = 0:
SUMEMISESQ = 0:
SUMEMISASQ = 0:
TESTRESULT = 0:
TOTCALEMISS = 0:
TOTACTEMISS = 0:
TOTEMFAC 7FEMISS = 0:
VA1 = 0:
VA2 = 0:
VA3 = 0:
VA4 = 0:
VEHNUM = 0:
RETURN
REM ..................................................................


REM ****DETAILED SEQUENTIAL STEADY-STATE RESULTS SUBROUTINE (REPORT1)******
REM ***********************************************************************
1000

     IF J = 1 THEN
        PRINT #2, "Sequential steady-state modes for "; CHOICE$(CYCLNUM)
        PRINT #2, "Cutrate for analysis is "; CUTRATE; "mph/sec"
        PRINT #2, "____________________________________________________________"
     END IF

     IF LASTCRIT = 0 AND AVGSPEED = 0 THEN
        PRINT #2, "IDLE EVENT #"; J
        PRINT #2, "CYCLE LENGTH", "START SPEED", "END SPEED", "AVG SPEED", "AVG ACCEL", "AVGPKE"
        PRINT #2, I, PREVSPD(COUNT - I - 1), PREVSPD(COUNT - 1), AVGSPEED, AVGACCEL, AVGPKE
        PRINT #2, "
```

```
    ELSEIF LASTCRIT = 0 AND AVGSPEED <> 0 THEN
        PRINT #2, "STEADY-STATE CRUISE EVENT #"; J
        PRINT #2, "CYCLE LENGTH", "START SPEED", "END SPEED", "AVG SPEED", "AVG ACCEL", "AVEPKE"
        PRINT #2, I, PREVSPD(COUNT - I - 1), PREVSPD(COUNT - 1), AVGSPEED, AVGACCEL, AVGPKE
        PRINT #2, "

    ELSEIF LASTCRIT = 1 THEN
        PRINT #2, "STEADY-STATE ACCELERATION EVENT #"; J
        PRINT #2, "CYCLE LENGTH", "START SPEED", "END SPEED", "AVG SPEED", "AVG ACCEL", "AVEPKE"
        PRINT #2, I, PREVSPD(COUNT - I - 1), PREVSPD(COUNT - 1), AVGSPEED, AVGACCEL, AVGPKE
        PRINT #2, "

    ELSE
        PRINT #2, "STEADY-STATE DECELERATION EVENT #"; J
        PRINT #2, "CYCLE LENGTH", "START SPEED", "END SPEED", "AVG SPEED", "AVG DECEL", "AVEPKE"
        PRINT #2, I, PREVSPD(COUNT - I - 1), PREVSPD(COUNT - 1), AVGSPEED, AVGACCEL, AVGPKE
        PRINT #2, "
        END IF
   RETURN
REM ____________________________________________________________________________


REM ******************SUMMARY REPORT SUBROUTINE (REPORT 2)*****************
REM **********************************************************************
2000

PRINT #3, "***** SUMMARY TABLE FOR TEST CYCLE  "; CHOICES$(CYCLNUM); " *****"
PRINT #3, "     Acceleration Cutoff Rate is  "; CUTRATE; " mph/sec"
PRINT #3, "     The FTP Bag2 Emission Rate is  "; BAG2RES; " grams/mile"
PRINT #3, "     The Idle Emission Rate is  "; IDLEFACT1; "grams/minute"
PRINT #3, "-----------------------------------------------------------------------------
-------"
PRINT #3, "-----------------------------------------------------------------------------
------"
PRINT #3, "IDLE EVENTS SUMMARY"
PRINT #3, "Event     Cycle      Start      End      Average   Average   Average   Caline"
PRINT #3, "  #       Length     Speed     Speed      Speed     Accel      PKE    Emissions"
PRINT #3, "          (secs)     (mph)     (mph)      (mph)   (mph/sec)  (S x A)   (grams)"
PRINT #3, "-----------------------------------------------------------------------------
-------"
FOR N = 1 TO IDLECNT
PRINT #3, USING "###.##    "; N; CYCLENI(N); STARTSPEEDI(N); ENDSPEEDI(N); SPDAVGI(N);
ACCAVGI(N); PKEAVGI(N); EMISSI(N)
NEXT N
PRINT #3, "Total Time in Idle (secs) ----- "; CYCLENTOTI
PRINT (13, "Total grams of CO emissions at Idle ---- "; EMISSITOT
PRINT #3, "                                                        "
```

```
PRINT #3, "----------------------------------------------------------------------------
-------"
PRINT #3, "----------------------------------------------------------------------------
------"
PRINT #3, "ACCELERATION EVENTS SUMMARY"
PRINT #3, "Event      Cycle      Start      End      Average   Average   Average   Caline"
PRINT #3, "  #        Length     Speed      Speed     Speed     Accel      PKE     Emissions"
PRINT #3, "           (secs)     (mph)      (mph)     (mph)    (mph/sec)  (S x A)   (grams)"
PRINT #3, "----------------------------------------------------------------------------
-------"
FOR N = 1 TO ACCCNT
PRINT #3, USING "###.##    "; N; CYCLENA(N); STARTSPEEDA(N); ENDSPEEDA(N); SPDAVGA(N);
ACCAVGA(N); PKEAVGA(N); EMISSA(N)
NEXT N
PRINT #3, "Total Time in Acceleration (secs)----- "; CYCLENTOTA
PRINT #3, "Total grams of CO emissions in Acceleration ---- "; EMISSATOT
PRINT #3, "

PRINT #3, "----------------------------------------------------------------------------
-------"
PRINT #3, "----------------------------------------------------------------------------
------"
PRINT #3, "CRUISE EVENTS SUMMARY"
PRINT #3, "Event      Cycle      Start      End      Average   Average   Average   Caline"
PRINT #3, "  #        Length     Speed      Speed     Speed     Accel      PKE     Emissions"
PRINT #3, "           (secs)     (mph)      (mph)     (mph)    (mph/sec)  (S x A)   (grams)"
PRINT #3, "----------------------------------------------------------------------------
-------"
FOR N = 1 TO CRUZCNT
PRINT #3, USING "###.##    "; N; CYCLENC(N); STARTSPEEDC(N); ENDSPEEDC(N); SPDAVGC(N);
ACCAVGC(N); PKEAVGC(N); EMISSC(N)
NEXT N
PRINT #3, "Total Time in Cruise (secs)----- "; CYCLENTOTC
PRINT #3, "Total grams of CO emissions in Cruise ---- "; EMISSCTOT
PRINT #3, "                                                              "

PRINT #3, "----------------------------------------------------------------------------
-------"
PRINT #3, "----------------------------------------------------------------------------
------"
PRINT #3, "DECELERATION EVENTS SUMMARY"
PRINT #3, "Event      Cycle      Start      End      Average   Average   Average   Caline"
PRINT #3, "  #        Length     Speed      Speed     Speed     Accel      PKE     Emissions"
PRINT #3, "           (secs)     (mph)      (mph)     (mph)    (mph/sec)  (S x A)   (grams)"
PRINT #3, "----------------------------------------------------------------------------
-------"
FOR N = 1 TO DECELCNT
PRINT #3, USING "###.##    "; N; CYCLEND(N); STARTSPEEDD(N); ENDSPEEDD(N) ; SPDAVGD(N);
ACCAVGD(N); PKEAVGD(N); EMISSD(N)
NEXT N
```

```
PRINT #3, "Total Time in Deceleration (secs)----- "; CYCLENTOTD
PRINT #3, "Total grams of CO emissions in Deceleration ---- "; EMISSDTOT
PRINT #3, -------------------------------------------------------------
PRINT #3,
PRINT #3, "Total time in all modes (Secs) ------------------ "; CYCLENTOT
PRINT #3, "Actual Emissions based on Cycle (Grams)--------- "; EMISSACT
PRINT #3, "
PRINT #3, "CALINE Emissions from Cycle (Grams)------------- "; EMISSCAL
PRINT #3, "Prediction Factor (CALINE/Actual) --------------- "; EMISSCAL / EMISSACT
PRINT #3, "
PRINT #3, "EMFAC 7F Emissions from Cycle (Grams)-------------- "; EMISSEMFAC 7F
PRINT #3, "Prediction Factor (EMFAC 7F/Actual) ---------------- "; EMISSEMFAC IF / EMISSACT

RETURN
REM -------------------------------------------------------------------

REM *************MULTIPLE RUN REPORT SUBROUTINE (REPORT3) ****************
REM ********************************************************************
3000

REM --------------------PRINT HEADER-----------------------
IF K = 1 THEN
PRINT #4, "Multiple Run Summary Table for "; CHOICE$(CYCLNUM)
PRINT #4, "Modal Cutrate Used is "; CUTRATE; "mph/sec"
PRINT #4, "-------------------------------------"
PRINT #4, "Vehicle  Mod CID  Bag-2     Idle    Measured  CALINE    EMFAC 7F    Actual"
PRINT #4, "Number    Yr       Rate     Factor     Rate   Estimate  Estimate  Emissions"
PRINT #4, "                 (g/mile)  (g/hour)  (g/mile)  (grams)   (grams)    (grams)"
PRINT #4, "==========================================================================="
END IF

REM ---------------------PRINT SUBSEQUENT PAGE HEADER------------------------
IF K = 54 OR K = 110 OR K = 166 OR K = 222 OR K = 278 OR K = 334 OR K = 390 OR K = 446 OR K = 502
THEN
PRINT #4, "Vehicle  Mod CID  Bag-2     Idle    Measured  CALINE    EMFAC 7F    Actual"
PRINT #4, "Number    Yr       Rate     Factor     Rate   Estimate  Estimate  Emissions"
PRINT #4, "                 (g/mile)  (g/hour)  (g/mile)  (grams)   (grams)    (grams)"
PRINT #4, "---------------------------------------------------======================="
END IF

REM -----------------------PRINT BODY OF REPORT-----------------------------
PRINT #4, USING "####### ": VEHNUM;
PRINT #4, USING "##  "; MODYR;
FRINT #4, USING "### "; CID;
PRINT #4, USING "#####.##  "; BAG2RES; IDLEFACTl; TESTRESULT; EMISSCAL; EMISSEMFAC 7F; EMISSACT

REM -----------------------PRINT TABLE TOTALS--------------------------------
```

```
IF K = ENDLOOP2 THEN
PRINT #4, "________________________________________________________________________
PRINT #4, "
PRINT #4, "Multiple Run Summary Table for  "; CHOICE$(CYCLNUM)
PRINT #4, "Number of Vehicles Tested on Cycle  "; ENDLOOP2
PRINT #4, "-------------------------- Emissions Summary ---------------------------"
PRINT #4, "Total Emissions Estimated by CALINE -----------"; TOTCALEMISS; "  Grams"
PRINT #4, "Total Emissions Estimated by EMFAC 7F ------------"; TOTEMFAC 7FEMISS; "  Grams"
PRINT 114, "Total Actual Emissions from Test Results ------"; TOTACTEMISS; "  Grams"
PRINT #4, "
PRINT #4, "Average Prediction Factor (CALINE/Actual) ---------"; TOTCALEMISS / TOTACTEMISS
PRINT #4, "Average Prediction Factor (EMFAC 7F/Actual) ----------"; TOTEMEAC 7FEMISS /
TOTACTEMISS
PRINT #4, "                                                          "
PRINT #4, "Mean CALINE estimated emission value --------------"; MEANEMISSC; "Grams"
PRINT #4, "Mean EMFAC 7F estimated emission value ---------------"; MEANEMISSE; "Grams"
PRINT #4, "Mean ACTUAL emission value -------------------------"; MEANEMISSA; "Grams"

PRINT #4, "Difference in means  (CALINE vs Actual) -----------"; MEANDIFF1; "Grams"
PRINT #4, "Difference in means  (EMFAC 7F vs Actual) -------------"; MEANDIFF2; "Grams"
PRINT #4, "
PRINT #4, "------------ Approximated ANOVA results for CALINE vs Actual -----------"
PRINT #4, "                                                      '
PRINT #4, "Sum of Squares for the Model ---------------------"; SSMODELl
PRINT #4, "Sum of Squares for Error --------------------------"; SSERRORl
PRINT #4, "Total Sum of Squares -------------------------------"; SSTOTALl
PRINT #4, "Psuedo R-Square Value for CALINE MODEL ------------"; RSQUARE1; " %"
PRINT #4, "Psuedo Adjusted R-Square Value for W I N E Model ---"; RSQUARElADJ; " %"
PRINT #4,
PRINT #4, "------------ Approximated ANOVA results for EMFAC 7F vs Actual -----------"
PRINT #4, "Sum of Squares for the Model ----------------------"; SSMODEL2
PRINT #4, "Sum of Squares for Error --------------------------"; SSERROR2
PRINT #4, "Total Sum of Squares -------------------------------"; SSTOTAL2
PRINT #4, "Psuedo R-Square Value for EMFAC 7F Model -------------"; RSQUARE2; " %"
PRINT #4, "Psuedo Adjusted R-Square Value for EMEAC 7F Model ----"; RSQUARE2ADJ; " %"
PRINT #4, "                                                              "
PRINT #4, "------------ CORRELATION COEFFICIENT results --------------------------"
PRINT #4, "Correlation Coefficient for CALINE Model ----------"; CORRC
PRINT #4, "Correlation Coefficient for EMFAC 7F Model -----------"; CORRE
PRINT #4, "Squared Correlation Coefficient for CALINE --------"; CORRC ^ 2
PRINT #4, "Squared Correlation Coefficient for EMFAC 7F ---------"; CORRE ^ 2
PRINT #4, "
PRINT #4, "------------ Mean Squared Prediction Errors ---------------------------"
PRINT #4, "Mean Squared Prediction Error for CALINE Model ----"; MSPEC; " Grams-2"
PRINT #4, "Mean Squared Prediction Error for EMFAC 7F Model -----"; MSPEE; "Grams^2"


END IF
RETURN
```

```
REM ----------------------------------------------------------------------


REM ******* MODEL PERFORMANCE SUMMARY SUBROUTINE (REPORT4&5) *************
REM ***********************************************************************
4000

REM --------------- PRINT HEADERS FOR REPORT 4 ---------------
IF CYCLNUM = 1 AND CUTRATE = .6 THEN
PRINT #6, "----------- Model Performance Summary Table for All Cycles ----------"
PRINT #6, "---------------------------------------------------------------------"
PRINT #6, "Cut-     Total     Total     Total     Caline   Caline   Emfac    Emfac"
PRINT #6, "rate     CALINE    EMFAC 7F    Actual    R-Sqr    Adj.     R-Sqr    Adj."
PRINT #6, "mph/s  Estimate  Estimate  Emissions          R-Sqr             R-Sqr"
PRINT #6, "---------------------------------------------------------------------"
END IF

I F CUTRATE = .6 THEN
PRINT #6, "                                                 "
PRINT #6, "Results for ----------- "; CHOICE$(CYCLNUM)
END I F

REM ----------------- PRINT BODY FOR REPORT 4 ----------------

PRINT #6, USING "#.##    "; CUTRATE;
PRINT #6, USING " #####.## "; TOTCALEMISS; TOTEMEAC 7FEMISS; TOTACTEMISS;
PRINT #6, USING " ###.#    "; RSQUAREl; RSQUAREIADJ; RSQUARE2; RSQUAREZADJ


REM --------------- PRINT HEADERS FOR REPORT 5 ---------------
IF CYCLNUM = 1 AND CUTRATE = .6 THEN
PRINT #7, "----------- Model Performance Summary Table for All Cycles ----------"
PRINT #7; "---------------------------------------------------------------------"
PRINT #7, "Cut-     CALINE    EMFAC 7F    Actual          SS             SS          "
PRINT #7, "rate      Mean      Mean      Mean         CALINE         EMFAC 7F        "
PRINT #7, "mph/s  Emission  Emission  Emission        Model          Model        "
PRINT #7, "---------------------------------------------------------------------"
END IF

I F CUTRATE = .6 THEN
PRINT #7, "
PRINT #7, "Results for ----------- 'I-, CHOICE$ (CYCLNUM)
END I F
REM ___-_______------  PRINT BODY FOR REPORT 5 ----------------
PRINT #7, USING "#.## "; CUTRATE;
PRINT #7, USING "#####.##  "; MEANEMISSC; MEANEMISSE; MEANEMISSA;
PRINT #7, USING "##########.#  "; SSMODEL1; SSMODELP

RETURN
REM ----------------------------------------------------------------------
```

Appendix B: Report 1 - Cycle Breakdown by Mode

```
Sequential steady-state modes for HIGH SPEED TEST CYCLE # 2
Cutrate for analysis is  .5 mph/sec

IDLE EVENT # 1
CYCLE LENGTH  START SPEED   END SPEED     AVG SPEED     AVG ACCEL     AVEPKE
 3             0             0             0             0             0

STEADY-STATE ACCELERATION EVENT # 2
CYCLE LENGTH  START SPEED   END SPEED     AVG SPEED     AVG ACCEL     AVEPKE
 20            0             42.4          24.98         2.12          52.96

STEADY-STATE CRUISE EVENT # 3
CYCLE LENGTH  START SPEED   END SPEED     AVG SPEED     AVG ACCEL     AVEPKE
 15            42.4          47.1          45.04         .31           14.11

STEADY-STATE ACCELERATION EVENT # 4
CYCLE LENGTH  START SPEED   END SPEED     AVG SPEED     AVG ACCEL     AVEPKE
 14            47.1          56.4          51.73         .66           34.36

STEADY-STATE CRUISE EVENT # 5
CYCLE LENGTH  START SPEED   END SPEED     AVG SPEED     AVG ACCEL     AVEPKE
 248           56.4          49.3          56.28        -.02          -1.61

STEADY-STATE DECELERATION EVENT # 6
CYCLE LENGTH  START SPEED   END SPEED     AVG SPEED     AVG DECEL     AVEPKE
 1             49.3          48.7          49           -.59          -29.39

STEADY-STATE CRUISE EVENT # 7
CYCLE LENGTH  START SPEED   END SPEED     AVG SPEED     AVG ACCEL     AVEPKE
 21            48.7          48.3          48.4         -.01          -.92

STEADY-STATE ACCELERATION EVENT # 8
CYCLE LENGTH  START SPEED   END SPEED     AVG SPEED     AVG ACCEL     AVEPKE
 1             48.3          49            48.65         .7            34.05

STEADY-STATE CRUISE EVENT # 9
CYCLE LENGTH  START SPEED   END SPEED     AVG SPEED     AVG ACCEL     AVEPKE
 3             49            48.9          49           -.03          -1.63

STEADY-STATE DECELERATION EVENT # 10
CYCLE LENGTH  START SPEED   END SPEED     AVG SPEED     AVG DECEL     AVEPKE
 3             48.9          46.2          47.55        -.9           -42.79

STEADY-STATE CRUISE EVENT # 11
CYCLE LENGTH  START SPEED   END SPEED     AVG SPEED     AVG ACCEL     AVEPKE
 3             46.2          46.2          46.14         0             0
```

```
STEADY-STATE ACCELERATION EVENT # 12
CYCLE LENGTH  START SPEED   END SPEED     AVG SPEED     AVG ACCEL     AVEPKE
 7             46.2          52.2          49.23         .85           42.2

STEADY-STATE CRUISE EVENT # 13
CYCLE LENGTH  START SPEED   END SPEED     AVG SPEED     AVG ACCEL     AVEPKE
 2             52.2          53            52.63         .39           21.05

STEADY-STATE ACCELERATION EVENT # 14
CYCLE LENGTH  START SPEED   END SPEED     AVG SPEED     AVG ACCEL     AVEPKE
 1             53            53.6          53.29         .59           31.97

STEADY-STATE CRUISE EVENT # 15
CYCLE LENGTH  START SPEED   END SPEED     AVG SPEED     AVG ACCEL     AVEPKE
 9             53.6          54.5          54.61         .1            5.46

STEADY-STATE DECELERATION EVENT # 16
CYCLE LENGTH  START SPEED   END SPEED     AVG SPEED     AVG DECEL     AVEPKE
 5             54.5          46.5          50.91         -1.6          -81.46

STEADY-STATE CRUISE EVENT # 17
CYCLE LENGTH  START SPEED   END SPEED     AVG SPEED     AVG ACCEL     AVEPKE
 5             46.5          46.8          46.29         .05           2.17

STEADY-STATE ACCELERATION EVENT # 18
CYCLE LENGTH  START SPEED   END SPEED     AVG SPEED     AVG ACCEL     AVEPKE
 5             46.8          50.2          48.5          .68           32.98

STEADY-STATE CRUISE EVENT # 19
CYCLE LENGTH  START SPEED   END SPEED     AVG SPEED     AVG ACCEL     AVEPKE
 2             50.2          51.1          50.66         .44           22.79

STEADY-STATE ACCELERATION EVENT # 20
CYCLE LENGTH  START SPEED   END SPEED     AVG SPEED     AVG ACCEL     AVEPKE
 1             51.1          51.7          51.4          .6            30.84

STEADY-STATE CRUISE EVENT # 21
CYCLE LENGTH  START SPEED   END SPEED     AVG SPEED     AVG ACCEL     AVEPKE
 25            51.7          51.7          52.04         0             0

STEADY-STATE DECELERATION EVENT # 22
CYCLE LENGTH  START SPEED   END SPEED     AVG SPEED     AVG DECEL     AVEPKE
 -             51.7          50.5          51.09         -.6           -30.66

STEADY-STATE CRUISE EVENT # 23
CYCLE LENGTH  START SPEED   END SPEED     AVG SPEED     AVG ACCEL     AVEPKE
 35            50.5          58.2          53.31         .22           11.72
```

STEADY-STATE ACCELERATION EVENT # 24

CYCLE LENGTH	START SPEED	END SPEED	AVG SPEED	AVG ACCEL	AVE PKE
1	58.2	58.8	58.5	.59	35.09

STEADY-STATE CRUISE EVENT # 25

CYCLE LENGTH	START SPEED	END SPEED	AVG SPEED	AVG ACCEL	AVE PKE
12	58.8	56.2	57.93	-.21	-12.55

STEADY-STATE DECELERATION EVENT # 26

CYCLE LENGTH	START SPEED	END SPEED	AVG SPEED	AVG DECEL	AVE PKE
2	56.2	54.6	55.43	-.8	-44.34

STEADY-STATE CRUISE EVENT # 27

CYCLE LENGTH	START SPEED	END SPEED	AVG SPEED	AVG ACCEL	AVE PKE
6	54.6	52	53.28	-.43	-23.09

STEADY-STATE DECELERATION EVENT # 28

CYCLE LENGTH	START SPEED	END SPEED	AVG SPEED	AVG DECEL	AVE PKE
21	52	0	27.87	-1.92	-53.61

IDLE EVENT # 29

CYCLE LENGTH	START SPEED	END SPEED	AVG SPEED	AVG ACCEL	AVE PKE
1	0	0	0	0	0

Appendix C: Report 2 - Summary Table For 1 Vehicle on Selected Cycle

```
***** SUMMARY TABLE FOR TEST CYCLE *****
    Acceleration Cutoff Rate is   .6  mph/sec
    The FTP Bag2 Emission Rate is   208  grams/mile
    The Idle Emission Rate is   2244.34 grams/minute
------------------------------------------------------------------------------------------
------------------------------------------------------------------------------------------
IDLE EVENTS SUMMARY
Event     Cycle      Start      End      Average   Average   Average   Caline
  #       Length     Speed      Speed    Speed     Accel      PKE      Emissions
          (secs)     (mph)      (mph)    (mph)     (mph/sec)  (S x A)  (grams)
------------------------------------------------------------------------------------------
  1.00     7.00      0.00       0.00     0.00       0.00      0.00      4.36
Total Time in Idle (secs) -----  7
Total grams of CO emissions at Idle ----  4.363995

------------------------------------------------------------------------------------------
------------------------------------------------------------------------------------------
ACCELERATION EVENTS SUMMARY
Event     Cycle      Start      End      Average   Average   Average   Caline
  #       Length     Speed      Speed    Speed     Accel      PKE      Emissions
          (secs)     (mph)      (mph)    (mph)     (mph/sec)  (S x A)  (grams)
------------------------------------------------------------------------------------------
  1.00    14.00      0.00      55.50    27.10       3.96     107.43    $1274.28
Total Time in Acceleration (secs) -----  14
Total grams of CO emissions in Acceleration ----  1274.278

     -------------------------------------------------------- ----------- -------- ---------
------------------------------------------------------------------------------------------
CRUISE EVENTS SUMMARY
Event     Cycle      Start      End      Average   Average   Average   Caline
  #       Length     Speed      Speed    Speed     Accel      PKE      Emissions
          (secs)     (mph)      (mph)    (mph)     (mph/sec)  (S x A)  (grams)
------------------------------------------------------------------------------------------
  1.00     2.00      0.00      60.00    20.00      30.00     600.00     1.08
Total Time in Cruise (secs) -----  2
Total grams of CO emissions in Cruise ----  1.08123

------------------------------------------------------------------------------------------
------------------------------------------------------------------------------------------
DECELERATION EVENTS SUMMARY
Event     Cycle      Start      End      Average   Average   Average   Caline
  #       Length     Speed      Speed    Speed     Accel      PKE      Emissions
          (secs)     (mph)      (mph)    (mph)     (mph/sec)  (S x A)  (grams)
------------------------------------------------------------------------------------------
  1.00    14.00     60.00       0.00    28.70      -4.28    %-123.00    13.09
Total Time in Deceleration (secs) -----  14
```

```
Total grams of CO emissions in Deceleration ----  13.09198
============================================================

Total time in all modes (Secs) ------------------  31
Actual Emissions based on Cycle (Grams) ---------  9.208889

CALINE Emissions from Cycle (Grams) -------------  1292.815
Prediction Factor (CALINE/Actual) ---------------  140.3878

EMFAC I F Emissions from Cycle (Grams) --------------  34.20444
Prediction Factor (EMFAC 7F/Actual) ----------------  3.114286
```

Appendix D: Report 3 - Summary of All Vehicles on a Cycle

Multiple Run Summary Table for FEDERAL TEST PROCEDURE, BAG 2
Modal Cutrate Used is 1 mph/sec: Option: Average Fleet Bag 2 and Idle Test Results

Vehicle Number	Mod Yr	CID	Bag-2 Rate (g/mile)	Idle Factor (g/hour)	Measured Rate (g/mile)	CALINE Estimate (grams)	EMFAC 7F Estimate (grams)	Actual Emissions (grams)
1029	80	231	11.08	9.48	0.10	37.07	42.65	0.38
1030	81	231	11.08	13.02	3.00	37.07	42.65	11.55
1031	81	98	11.08	0.00	5.10	37.07	42.65	19.63
1032	80	98	11.08	162.66	25.00	37.07	42.65	96.22
1033	81	98	11.08	32.04	5.10	37.07	42.65	19.63
3027	81	302	11.08	505.41	0.10	37.07	42.65	0.38
3034	81	255	11.08	377.12	8.10	37.07	42.65	31.18
3040	81	267	11.08	0.00	0.20	37.07	42.65	0.77
3041	81	267	11.08	0.00	0.40	37.07	42.65	1.54
3042	81	305	11.08	13.86	0.70	37.07	42.65	2.69
3043	81	267	11.08	4.90	3.10	37.07	42.65	11.93
3044	81	307	11.08	6.26	0.20	37.07	42.65	0.77
3046	81	267	11.08	0.32	14.40	37.07	42.65	55.42
3048	81	267	11.08	1.04	2.00	37.07	42.65	7.70
3050	81	140	11.08	100.00	1.40	37.07	42.65	5.39
3078	81	305	11.08	29.04	6.70	37.07	42.65	25.79
3081	81	305	11.08	10.96	0.60	37.07	42.65	2.31
3110	81	91	11.08	0.26	0.90	37.07	42.65	3.46
3111	81	91	11.08	0.00	0.50	37.07	42.65	1.92
3112	81	91	11.08	5.46	4.30	37.07	42.65	16.55
3113	81	91	11.08	31.32	2.80	37.07	42.65	10.78
3114	81	85	11.08	0.00	0.50	37.07	42.65	1.92
3115	81	91	11.08	0.63	2.20	37.07	42.65	8.47
3116	81	108	11.08	7.24	0.90	37.07	42.65	3.46
3117	81	108	11.08	7.36	57.10	37.07	42.65	219.77
3119	81	108	11.08	2.38	0.70	37.07	42.65	2.69
3120	81	91	11.08	39.18	1.60	37.07	42.65	6.16
3121	81	108	11.08	2.12	1.20	37.07	42.65	4.62
3122	81	108	11.08	90.16	0.30	37.07	42.65	1.15
3124	81	108	11.08	2.11	0.60	37.07	42.65	2.31
3125	81	168	11.08	2.40	0.90	37.07	42.65	3.46
3126	81	168	11.08	2.84	0.80	37.07	42.65	3.08
3128	81	144	11.08	1.29	1.30	37.07	42.65	5.00
3130	81	144	11.08	3.86	2.00	37.07	42.65	7.70
3133	81	105	11.08	0.32	0.70	37.07	42.65	2.69
3134	81	105	11.08	35.09	1.20	37.07	42.65	4.62
3137	81	302	11.08	813.35	52.90	37.07	42.65	203.61
3139	81	302	11.08	2244.34	208.00	37.07	42.65	800.57
3140	81	302	11.08	893.21	30.50	37.07	42.65	117.39

Vehicle Number	Mod Yr	CID	Bag-2 Rate (g/mile)	Idle Factor (g/hour)	Measured Rate (g/mile)	CALINE Estimate (grams)	EMFAC 7F Estimate (grams)	Actual Emissions (grams)
3141	81	302	11.08	548.71	48.70	37.07	42.65	187.44
3142	81	260	11.08	9.38	0.30	37.07	42.65	1.15
3143	81	267	11.08	8.35	4.00	37.07	42.65	15.40
3145	77	350	11.08	297.38	17.60	37.07	42.65	67.74
3147	77	250	11.08	16.32	4.30	37.07	42.65	16.55
3148	81	260	11.08	14.99	0.10	37.07	42.65	0.38
3149	81	260	11.08	5.76	0.60	37.07	42.65	2.31
3165	81	151	11.08	10.78	2.80	37.07	42.65	10.78
3166	81	151	11.08	4.22	0.00	37.07	42.65	0.00
3167	81	151	11.08	11.59	0.00	37.07	42.65	0.00
3169	81	151	11.08	15.12	0.00	37.07	42.65	0.00
3171	81	151	11.08	16.50	0.10	37.07	42.65	0.38
3172	81	151	11.08	6.66	0.00	37.07	42.65	0.00
3173	81	151	11.08	13.44	0.30	37.07	42.65	1.15
3174	91	151	11.08	0.00	0.20	37.07	42.65	0.77
3175	81	151	11.08	7.32	0.00	37.07	42.65	0.00
3183	81	151	11.08	3.36	0.90	37.07	42.65	3.46
3187	81	151	11.08	0.19	0.30	37.07	42.65	1.15
3190	81	151	11.08	15.71	0.00	37.07	42.65	0.00
3191	81	151	11.08	4.45	0.30	37.07	42.65	1.15
3194	81	200	11.08	269.75	0.40	37.07	42.65	1.54
3195	81	200	11.08	27.04	0.00	37.07	42.65	0.00
3196	81	200	11.08	22.64	52.80	37.07	42.65	203.22
3198	81	200	11.08	805.06	74.20	37.07	42.65	285.59
3199	81	200	11.08	696.31	0.00	37.07	42.65	0.00
3200	81	200	11.08	627.30	0.80	37.07	42.65	3.08
3205	81	200	11.08	1895.28	76.40	37.07	42.65	294.06
3206	81	200	11.08	169.32	0.50	37.07	42.65	1.92
3238	81	200	11.08	376.53	0.10	37.07	42.65	0.38
3210	81	200	11.08	672.49	2.30	37.07	42.65	8.85
3211	81	200	11.08	2.10	0.30	37.07	42.65	1.15
3212	81	109	11.08	6.41	3.70	37.07	42.65	14.24
3215	81	109	11.08	10.87	2.10	37.07	42.65	8.08
3216	81	109	11.08	294.20	46.20	37.07	42.65	177.82
3218	81	109	11.08	7.79	3.30	37.07	42.65	12.70
3219	81	302	11.08	747.19	9.60	37.07	42.65	36.95
3221	81	252	11.08	13.99	0.30	37.07	42.65	1.15
3266	81	265	11.08	3.92	0.10	37.07	42.65	0.38
3304	81	307	11.08	3.42	0.30	37.07	42.65	1.15
3305	81	307	11.08	17.88	0.50	37.07	42.65	1.92
3311	81	307	11.08	116.52	0.10	37.07	42.65	0.38
3312	81	307	11.08	207.83	2.60	37.07	42.65	10.01
3316	81	307	11.08	6.13	0.20	37.07	42.65	0.77
3330	78	305	11.08	10.94	0.80	37.07	42.65	3.08
3331	78	250	11.08	369.65	24.40	37.07	42.65	93.91
3332	78	250	11.08	109.05	13.00	37.07	42.65	50.04

Vehicle Number	Mod Yr	CID	Bag-2 Rate (g/mile)	Idle Factor (g/hour)	Measured Rate (g/mile)	CALINE Estimate (grams)	EMFAC 7F Estimate (grams)	Actual Emissions (grams)
3333	78	231	11.08	199.24	7.30	37.07	42.65	28.10
3334	78	350	11.08	364.24	60.30	37.07	42.65	232.09
3337	78	171	11.08	1202.77	36.20	37.07	42.65	139.33
3338	78	351	11.08	1062.77	12.50	37.07	42.65	48.11
3339	78	140	11.08	430.62	42.10	37.07	42.65	162.04
3340	78	231	11.08	519.74	16.10	37.07	42.65	61.97
3341	78	97	11.08	8.25	17.10	37.07	42.65	65.82
3342	78	400	11.08	2321.95	21.00	37.07	42.65	80.83
3343	78	305	11.08	427.82	37.90	37.07	42.65	145.87
3344	78	134	11.08	28.35	13.30	37.07	42.65	51.19
3345	78	351	11.08	1189.70	139.00	37.07	42.65	535.00
3350	78	301	11.08	12.93	10.60	37.07	42.65	40.80
3351	81	265	11.08	1.45	2.10	37.07	42.65	8.08
3355	81	140	11.08	368.64	0.80	37.07	42.65	3.08
3359	81	140	11.08	7.59	4.80	37.07	42.65	18.47
3365	81	140	11.08	257.71	1.20	37.07	42.65	4.62
3368	81	140	11.08	3.89	2.70	37.07	42.65	10.39
3371	81	140	11.08	283.45	30.00	37.07	42.65	115.47
3374	77	400	11.08	1078.71	0.70	37.07	42.65	2.69
3377	77	351	11.08	2344.70	115.40	37.07	42.65	444.16
3379	77	351	11.08	1367.74	60.00	37.07	42.65	230.93
3380	77	351	11.08	811.95	0.60	37.07	42.65	2.31
3381	77	351	11.08	2749.47	175.00	37.07	42.65	673.56
3382	77	225	11.08	66.19	16.30	37.07	42.65	62.74
3383	77	134	11.08	781.06	89.80	37.07	42.65	345.63
3386	77	400	11.08	1445.94	2.00	37.07	42.65	7.70
3387	77	351	11.08	26.87	17.30	37.07	42.65	66.59
3389	77	305	11.08	23.16	1.30	37.07	42.65	5.00
3390	77	425	11.08	1800.17	120.80	37.07	42.65	464.95
3393	77	250	11.08	1384.20	8.00	37.07	42.65	30.79
3394	77	305	11.08	0.31	0.10	37.07	42.65	0.38
3397	77	140	11.08	485.48	16.50	37.07	42.65	63.51
3398	77	302	11.08	1209.45	68.10	37.07	42.65	262.11
3400	77	460	11.08	62.20	1.60	37.07	42.65	6.16
3417	78	351	11.08	5.89	12.00	37.07	42.65	46.19
3418	78	97	11.08	23.54	4.70	37.07	42.65	18.09
3419	78	134	11.08	159.33	9.70	37.07	42.65	37.33
3420	78	400	11.08	3362.14	70.10	37.07	42.65	269.81
3421	78	350	11.08	344.78	27.70	37.07	42.65	106.61
3422	78	425	11.08	19.04	5.80	37.07	42.65	22.32
3423	78	200	11.08	1224.31	71.80	37.07	42.65	276.35
3424	78	301	11.08	0.70	0.60	37.07	42.65	2.31
3429	78	200	11.08	523.50	38.30	37.01	42.65	147.41
3431	78	351	11.08	31.95	11.40	37.07	42.65	43.88
3432	78	250	11.08	493.00	32.30	37.07	42.65	124.32
3433	78	425	11.08	940.08	70.50	37.07	42.65	271.35

Vehicle Number	Mod Yr	CID	Bag-2 Rate (g/mile)	Idle Factor (g/hour)	Measured Rate (g/mile)	CALINE Estimate (grams)	EMFAC 7F Estimate (grams)	Actual Emissions (grams)
3434	78	140	11.08	530.26	106.30	37.07	42.65	409.14
3435	78	98	11.08	463.93	2.00	37.07	42.65	7.70
3436	78	250	11.08	2417.41	95.10	37.07	42.65	366.03
3438	78	301	11.08	68.18	7.00	37.07	42.65	26.94
3439	78	97	11.08	24.73	9.80	37.07	42.65	37.72
3440	81	252	11.08	8.69	0.60	37.07	42.65	2.31
3463	81	91	11.08	0.80	0.80	37.07	42.65	3.08
3465	81	107	11.08	0.32	0.00	37.07	42.65	0.00
3468	81	91	11.08	2.52	0.50	37.07	42.65	1.92
3469	81	107	11.08	0.31	1.30	37.07	42.65	5.00
3471	81	91	11.08	3.78	1.00	37.07	42.65	3.85
3472	81	107	11.08	0.00	2.60	37.07	42.65	10.01
3475	81	107	11.08	0.00	2.30	37.07	42.65	8.85
3476	81	107	11.08	0.00	1.30	37.07	42.65	5.00
4004	81	231	11.08	19.81	5.00	37.07	42.65	19.24
4005	81	231	11.08	41.77	5.40	37.07	42.65	20.78
4011	81	231	11.08	31.19	5.50	37.07	42.65	21.17
4012	81	231	11.08	10.42	4.70	37.07	42.65	18.09
4019	81	231	11.08	28.20	6.20	37.07	42.65	23.86
4032	81	151	11.08	2.57	2.50	37.07	42.65	9.62
4035	81	151	11.08	0.68	0.60	37.07	42.65	2.31
4038	81	151	11.08	7.51	0.90	37.07	42.65	3.46
4052	81	98	11.08	11.16	6.80	37.07	42.65	26.17
4053	81	98	11.08	74.27	4.40	37.07	42.65	16.94
4055	81	98	11.08	16.06	11.70	37.07	42.65	45.03
4059	81	98	11.08	9.62	5.30	37.07	42.65	20.40
4080	81	98	11.08	34.34	22.20	37.07	42.65	85.45
4082	81	98	11.08	11.17	2.50	37.07	42.65	9.62
4104	81	135	11.08	12.69	1.10	37.07	42.65	4.23
4106	81	135	11.08	9.04	2.40	37.07	42.65	9.24
4107	81	135	11.08	37.92	2.80	37.07	42.65	10.78
4145	81	108	11.08	0.00	1.00	37.07	42.65	3.85
4148	81	91	11.08	4.62	4.00	37.07	42.65	15.40
4151	81	91	11.08	0.16	3.20	37.07	42.65	12.32
4154	81	107	11.08	3.11	1.80	37.07	42.65	6.93
4155	81	107	11.08	5.08	5.50	37.07	42.65	21.17
4157	81	107	11.08	1.11	6.50	37.07	42.65	25.02
4160	81	107	11.08	0.00	1.30	37.07	42.65	5.00
4163	81	140	11.08	86.21	95.90	37.07	42.65	369.11
4164	81	140	11.08	0.16	18.30	37.07	42.65	70.43
4165	81	140	11.08	292.31	13.80	37.07	42.65	53.11
4193	81	109	11.08	23.87	3.30	37.07	42.65	12.70
4194	81	109	11.08	8.71	2.70	37.07	42.65	10.39
4196	81	260	11.08	311.92	17.30	37.07	42.65	66.59
4209	81	89	11.08	11.61	1.40	37.07	42.65	5.39
4211	81	89	11.08	0.65	4.60	37.07	42.65	17.70

Vehicle Number	Mod Yr	CID	Bag-2 Rate (g/mile)	Idle Factor (g/hour)	Measured Rate (g/mile)	CALINE Estimate (grams)	EMFAC 7F Estimate (grams)	Actual Emissions (grams)
4230	81	302	11.08	220.26	0.30	37.07	42.65	1.15
4238	81	98	11.08	0.64	0.20	37.07	42.65	0.77
4240	81	258	11.08	19.32	0.10	37.07	42.65	0.38
4242	81	168	11.08	48.28	6.60	37.07	42.65	25.40
4244	81	120	11.08	5.18	2.20	37.07	42.65	8.47
4256	82	110	11.08	6.05	0.60	37.07	42.65	2.31
4264	82	110	11.08	3.65	0.50	37.07	42.65	1.92
4266	82	151	11.08	4.93	1.80	37.07	42.65	6.93
4271	82	151	11.08	45.09	4.40	37.07	42.65	16.94
4277	82	151	11.08	8.81	2.00	37.07	42.65	7.70
4282	83	110	11.08	10.53	0.80	37.07	42.65	3.08
4290	83	110	11.08	3.39	1.20	37.07	42.65	4.62
4292	83	151	11.08	7.41	3.00	37.07	42.65	11.55
4295	83	151	11.08	14.14	4.00	37.07	42.65	15.40
4296	83	151	11.08	22.06	3.90	37.07	42.65	15.01
4299	83	151	11.08	7.11	2.30	37.07	42.65	8.85
4305	83	151	11.08	4.30	2.30	37.07	42.65	8.85
4310	83	98	11.08	21.99	1.20	37.07	42.65	4.62
4313	83	98	11.08	10.92	1.00	37.07	42.65	3.85
4314	83	98	11.08	1.09	1.00	37.07	42.65	3.85
4315	83	98	11.08	30.07	1.40	37.07	42.65	5.39
4319	83	98	11.08	6.57	0.50	37.07	42.65	1.92
4324	83	98	11.08	1.80	2.10	37.07	42.65	8.08
4325	83	98	11.08	18.88	0.00	37.07	42.65	0.00
4330	83	200	11.08	422.85	*0.00*	37.07	42.65	*0.00*
4331	83	200	11.08	309.41	0.40	37.07	42.65	1.54
4333	83	200	11.08	1.61	0.20	37.07	42.65	0.77
4337	83	131	11.08	*0.00*	0.80	37.07	42.65	3.08
4363	83	85	11.08	2.16	0.90	37.07	42.65	3.46
5209	83	98	11.08	20.44	3.40	37.07	42.65	13.09
5210	83	98	11.08	62.19	13.40	37.07	42.65	51.58
5213	83	140	11.08	39.61	10.00	37.07	42.65	38.49
5215	83	140	11.08	368.17	6.80	37.07	42.65	26.17
5216	83	140	11.08	47.51	8.30	37.07	42.65	31.95
5217	83	140	11.08	15.03	6.20	37.07	42.65	23.86
5218	83	140	11.08	112.15	4.30	37.07	42.65	16.55
5227	83	121	11.08	12.20	5.60	37.07	42.65	21.55
5229	83	121	11.08	*0.00*	0.10	37.07	42.65	0.38
5230	83	121	11.08	13.16	8.70	37.07	42.65	33.49
5238	84	135	11.08	88.93,	156.20	37.07	42.65	601.20
5264	83	140	11.08	11.72	2.40	37.07	42.65	9.24
5265	83	140	11.08	65.10	9.30	37.07	42.65	35.79
5266	83	121	11.08	1.73	0.70	37.07	42.65	2.69
5277	83	98	11.08	59.14	4.20	37.07	42.65	16.17
6014	84	231	11.08	112.07	2.50	37.07	42.65	9.62
6016	84	231	11.08	5.88	0.40	37.07	42.65	1.54

Vehicle Number	Mod Yr	CID	Bag-2 Rate (g/mile)	Idle Factor (g/hour)	Measured Rate (g/mile)	CALINE Estimate (grams)	EMFAC 7F Estimate (grams)	Actual Emissions (grams)
6027	84	302	11.08	2.57	0.50	37.07	42.65	1.92
6030	84	231	11.08	30.19	4.50	37.07	42.65	17.32
6031	84	135	11.08	4.94	4.90	37.07	42.65	18.86
6049	84	110	11.08	5.21	4.60	37.07	42.65	17.70
6051	84	110	11.08	8.12	5.30	37.07	42.65	20.40
1	87	151	11.08	4.13	1.50	37.07	42.65	5.71
2	87	173	11.08	43.84	1.50	37.07	42.65	5.77
3	87	182	11.08	1047.46	77.20	37.07	42.65	297.13
4	87	231	11.08	1.33	0.30	37.07	42.65	1.15
5	86	110	11.08	4.72	0.50	37.07	42.65	1.92
7	87	182	11.08	40.35	5.80	37.07	42.65	22.32
9	87	151	11.08	16.98	1.10	37.07	42.65	4.23
10	87	173	11.08	12.59	2.20	37.07	42.65	8.47
11	87	173	11.08	2.89	3.70	37.07	42.65	14.24
14	87	151	11.08	2.32	0.90	37.07	42.65	3.46
17	87	302	11.08	1.78	0.60	37.07	42.65	2.31
19	87	135	11.08	8.34	0.00	37.07	42.65	0.00
20	87	231	11.08	1.39	0.80	37.07	42.65	3.08
21	87	302	11.08	1.05	0.50	37.07	42.65	1.92
25	87	182	11.08	57.74	2.40	37.07	42.65	9.24
29	87	302	11.08	16.48	0.60	37.07	42.65	2.31
34	87	182	11.08	62.08	1.70	37.07	42.65	6.54
35	87	121	11.08	24.68	2.30	37.07	42.65	8.85
43	87	151	11.08	15.33	1.60	37.07	42.65	6.16
45	87	231	11.08	2.43	1.60	37.07	42.65	6.16
46	87	182	11.08	59.55	3.10	37.07	42.65	11.93
47	87	121	11.08	63.09	3.70	37.07	42.65	14.24
48	87	121	11.08	202.51	3.40	37.07	42.65	13.09
49	87	231	11.08	1.29	0.50	37.07	42.65	1.92
51	87	302	11.08	6.47	1.00	37.07	42.65	3.85
52	87	302	11.08	8.03	1.40	37.07	42.65	5.39
54	87	302	11.08	3.73	1.70	37.07	42.65	6.54
56	87	121	11.08	217.99	5.80	37.07	42.65	22.32
57	87	231	11.08	1.78	0.80	37.07	42.65	3.08
61	87	121	11.08	5.83	4.00	37.07	42.65	15.40
62	87	151	11.08	12.56	1.50	37.07	42.65	5.77
63	87	121	11.08	33.51	3.50	37.07	42.65	13.47
65	87	182	11.08	66.95	4.90	37.07	42.65	18.86
68	85	173	11.08	20.53	3.50	37.07	42.65	13.47
70	88	119	11.08	0.98	0.90	37.07	42.65	3.46
73	85	173	11.08	5.17	6.10	37.07	42.65	23.48
75	87	151	11.08	5.29	1.70	37.07	42.65	6.54
76	85	173	11.08	2.53	1.40	37.07	42.65	5.39
77	87	231	11.08	0.34	0.30	37.07	12.65	1.15
78	86	231	11.08	698.66	2.10	37.07	42.65	8.08
80	88	119	11.08	0.01	0.10	37.07	42.65	0.38

Vehicle Number	Mod Yr	CID	Bag-2 Rate (g/mile)	Idle Factor (g/hour)	Measured Rate (g/mile)	CALINE Estimate (grams)	EMFAC 7F Estimate (grams)	Actual Emissions (grams)
82	85	173	11.08	7.70	5.70	37.07	42.65	21.94
85	85	173	11.08	10.36	3.20	37.07	42.65	12.32
86	88	181	11.08	109.86	4.60	37.07	42.65	17.70
87	88	119	11.08	0.06	0.10	37.07	42.65	0.38
91	88	181	11.08	52.44	2.80	37.07	42.65	10.78
92	88	181	11.08	86.01	4.70	37.07	42.65	18.09
93	86	231	11.08	111.60	1.70	37.07	42.65	6.54
95	89	152	11.08	24.64	0.60	37.07	42.65	2.31
96	88	181	11.08	47.59	1.50	37.07	42.65	5.77
97	88	181	11.08	39.16	4.50	37.07	42.65	17.32
98	88	119	11.08	62.38	0.70	37.07	42.65	2.69
104	88	181	11.08	80.58	2.30	37.07	42.65	8.85
105	86	231	11.08	205.11	0.80	37.07	42.65	3.08
106	86	231	11.08	5.13	0.10	37.07	42.65	0.38
107	86	231	11.08	221.48	0.20	37.07	42.65	0.77
108	87	97	11.08	1.98	12.70	37.07	42.65	48.88
109	89	152	11.08	21.58	0.50	37.07	42.65	1.92
112	89	204	11.08	11.68	1.70	37.07	42.65	6.54
113	89	204	11.08	39.08	0.00	37.07	42.65	0.00
114	89	204	11.08	18.03	0.20	37.07	42.65	0.77
119	89	204	11.08	17.16	0.00	37.07	42.65	0.00
120	89	152	11.08	17.24	0.70	37.07	42.65	2.69
126	89	152	11.08	14.50	0.50	37.07	42.65	1.92
127	87	305	11.08	30.22	0.90	37.07	42.65	3.46
128	87	173	11.08	134.99	7.40	37.07	42.65	28.48
129	89	302	11.08	3.81	0.10	37.07	42.65	0.38
131	87	173	11.08	46.75	2.70	37.07	42.65	10.39
133	89	152	11.08	15.02	0.60	37.07	42.65	2.31
134	87	173	11.08	42.78	0.60	37.07	42.65	2.31
136	87	173	11.08	41.65	1.00	37.07	42.65	3.85
138	89	152	11.08	20.97	0.70	37.07	42.65	2.69
140	87	173	11.08	20.28	1.70	37.07	42.65	6.54
142	89	204	11.08	124.52	0.50	37.07	42.65	1.92
143	89	204	11.08	37.30	0.40	37.07	42.65	1.54
145	87	119	11.08	1.81	3.10	37.07	42.65	11.93
146	87	119	11.08	4.22	0.90	37.07	42.65	3.46
147	89	204	11.08	35.06	0.10	37.07	42.65	0.38
148	87	119	11.08	2.17	2.80	37.07	42.65	10.78
149	89	122	11.08	0.45	0.30	37.07	42.65	1.15
150	89	302	11.08	5.77	1.00	37.07	42.65	3.85
803	86	135	11.08	68.78	0.90	37.07	42.65	3.46
822	86	135	11.08	4.04	5.50	37.07	42.65	21.17
840	96	135	11.08	16.21	74.70	37.07	32.65	287.51
842	86	135	11.08	2514.32	258.70	37.07	42.65	995.71
856	86	135	11.08	3.21	75.10	37.07	42.65	289.05
859	86	135	11.08	1238.93	321.50	37.07	42.65	1237.42

Vehicle Number	Mod Yr	CID	Bag-2 Rate (g/mile)	Idle Factor (g/hour)	Measured Rate (g/mile)	CALINE Estimate (grams)	EMFAC 7F Estimate (grams)	Actual Emissions (grams)
874	86	135	11.08	455.02	228.60	37.07	42.65	879.86
1008	87	119	11.08	0.86	0.90	37.07	42.65	3.46
1011	89	122	11.08	0.07	0.20	37.07	42.65	0.77
1012	89	122	11.08	0.39	0.30	37.07	42.65	1.15
1016	89	122	11.08	0.33	0.40	37.07	42.65	1.54
6036	84	302	11.08	93.37	0.20	37.07	42.65	0.77
6075	82	110	11.08	3.65	3.50	37.07	42.65	13.47
6090	82	249	11.08	37.58	1.70	37.07	42.65	6.54
6105	85	231	11.08	67.22	1.10	37.07	42.65	4.23
6119	85	173	11.08	11.69	1.30	37.07	42.65	5.00
6120	85	173	11.08	6.98	0.90	37.07	42.65	3.46
6122	85	173	11.08	5.20	1.40	37.07	42.65	5.39
6123	85	173	11.08	0.95	1.00	37.07	42.65	3.85
6128	82	302	11.08	1.16	0.30	37.07	42.65	1.15
6132	85	231	11.08	63.54	2.50	37.07	42.65	9.62
6135	85	231	11.08	0.00	0.00	37.07	42.65	0.00
6136	85	231	11.08	77.48	0.10	37.07	42.65	0.38
6137	85	231	11.08	125.04	0.30	37.07	42.65	1.15
6138	85	231	11.08	148.06	0.10	37.07	42.65	0.38
6139	85	231	11.08	100.28	0.20	37.07	42.65	0.77
6140	85	302	11.08	740.81	0.40	37.07	42.65	1.54
6141	85	302	11.08	454.33	0.30	37.07	42.65	1.15
6143	82	151	11.08	7.21	3.10	37.07	42.65	11.93
6144	82	151	11.08	428.01	1.50	37.0?	42.65	5.77
6145	82	151	11.08	10.99	3.20	37.07	42.65	12.32
6146	82	151	11.08	27.83	12.30	37.07	42.65	47.34
6147	82	151	11.08	0.00	0.60	37.07	42.65	2.31
6149	82	225	11.08	56.49	1.00	37.07	42.65	3.85
6150	82	305	11.08	4.44	0.10	37.07	42.65	0.38
6152	83	135	11.08	0.82	1.10	37.07	42.65	4.23
6153	85	121	11.08	10.46	1.50	37.07	42.65	5.77
6154	85	121	11.08	7.49	0.40	37.07	42.65	1.54
6180	85	302	11.08	182.76	0.40	37.07	42.65	1.54
6181	85	110	11.08	3.80	2.30	37.07	42.65	8.85
6207	85	135	11.08	0.64	0.30	37.07	42.65	1.15
6208	85	135	11.08	2.96	0.90	37.07	42.65	3.46
6209	85	135	11.08	0.16	7.90	37.07	42.65	30.41
6211	85	135	11.08	7.12	1.10	37.07	42.65	4.23
6213	85	135	11.08	3.77	1.10	37.07	42.65	4.23
6214	85	135	11.08	10.19	0.40	37.07	42.65	1.54
6215	85	231	11.08	37.53	0.10	37.07	42.65	0.38
6216	85	181	11.08	0.00	0.00	37.07	42.65	0.00
6217	85	181	11.08	6.51	0.00	37.07	42.65	0.00
6218	85	135	11.08	6.25	1.90	37.07	42.65	7.31
6219	85	181	11.08	11.46	1.00	37.07	42.65	3.85
6220	85	181	11.0f?	1.92	0.00	37.07	42.65	0.00

Vehicle Number	Mod Yr	CID	Bag-2 Rate (g/mile)	Idle Factor (g/hour)	Measured Rate (g/mile)	CALINE Estimate (grams)	EMFAC 7F Estimate (grams)	Actual Emissions (grams)
6221	85	181	11.08	0.47	0.40	37.07	42.65	1.54
6222	85	98	11.08	16.33	0.10	37.07	42.65	0.38
6223	85	98	11.08	4.55	0.10	37.07	42.65	0.38
6224	85	98	11.08	7.19	2.70	37.07	42.65	10.39
6233	85	98	11.08	4.83	0.40	37.07	42.65	1.54
6234	82	151	11.08	11.84	3.50	37.07	42.65	13.47
6235	84	302	11.06	18.55	0.40	37.07	42.65	1.54
6236	82	151	11.08	0.32	1.30	37.07	42.65	5.00
6237	83	151	11.08	98.73	3.10	37.07	42.65	11.93
6238	83	151	11.08	0.32	1.90	37.07	42.65	7.31
6240	83	302	11.08	172.88	0.50	37.07	42.65	1.92
6242	82	110	11.08	4.52	4.10	37.07	42.65	15.78
6243	82	110	11.08	20.30	5.80	37.07	42.65	22.32
6244	82	110	11.08	39.98	5.00	37.07	42.65	19.24
6247	81	258	11.08	26.78	7.30	37.07	42.65	28.10
6249	82	225	11.08	1.14	0.70	37.07	42.65	2.69
6250	83	225	11.08	54.14	1.10	37.07	42.65	4.23
6252	83	302	11.08	13.43	1.20	37.07	42.65	4.62
6265	82	151	11.08	16.45	4.90	37.07	42.65	18.86
6266	83	151	11.08	42.61	2.80	37.07	42.65	10.78
6267	85	135	11.08	2.89	1.20	37.07	42.65	4.62
6271	85	112	11.08	0.00	0.20	37.07	42.65	0.77
6272	85	112	11.08	126.04	0.30	37.07	42.65	1.15
6273	85	135	11.06	5.29	1.80	37.07	42.65	6.93
6274	85	181	11.08	13.55	0.00	37.07	42.65	0.00
7001	83	302	11.08	16.85	6.50	37.07	42.65	25.02
7002	85	181	11.08	115.25	24.90	37.07	42.65	95.84
7004	85	112	11.08	126.02	1.00	37.07	42.65	3.85
7005	85	98	11.08	0.66	1.20	37.07	42.65	4.62
7007	83	302	11.08	4.42	15.60	37.07	42.65	60.04
7039	81	231	11.08	138.05	12.40	37.07	42.65	47.73
7044	81	305	11.08	1.90	0.60	37.07	42.65	2.31
7046	82	305	11.08	2.04	13.60	37.07	42.65	52.34
7047	81	231	11.08	333.88	28.60	37.07	42.65	110.08
7049	81	200	11.08	0.47	2.20	37.07	42.65	8.47
7052	81	305	11.08	489.40	29.80	37.07	42.65	114.70
7061	81	200	11.08	97.61	0.60	37.07	42.65	2.31
7062	83	121	11.08	8.03	5.20	37.07	42.65	20.01
7064	82	305	11.08	15.72	15.30	37.07	42.65	58.89
7066	81	305	11.08	3.13	0.40	37.07	42.65	1.54
7068	81	108	11.08	3.29	1.70	37.07	42.65	6.54
7071	81	108	11.08	0.00	2.70	37.07	42.65	10.39
7072	81	231	11.08	33.61	5.00	37.07	42.65	19.24
7075	81	108	11.08	3.44	4.90	37.07	42.65	18.86
7077	81	200	11.08	412.90	0.30	31.07	42.65	1.15
7078	a3	121	11.08	43.56	8.40	37.07	42.65	32.33

Vehicle Number	Mod Yr	CID	Bag-2 Rate (g/mile)	Idle Factor (g/hour)	Measured Rate (g/mile)	CALINE Estimate (grams)	EMFAC 7F Estimate (grams)	Actual Emissions (grams)
7079	81	200	11.08	27.00	1.30	37.07	42.65	5.00
7081	81	200	11.08	15.15	0.40	37.07	42.65	1.54
7084	83	121	11.08	2.31	4.50	37.07	42.65	17.32
7086	81	305	11.08	87.01	7.00	37.07	42.65	26.94
7087	81	108	11.08	0.50	1.40	37.07	42.65	5.39
7088	81	305	11.08	13.27	10.80	37.07	42.65	41.57
7093	81	140	11.08	7.45	1.10	37.07	42.65	4.23
1096	83	151	11.08	5.95	3.20	37.07	42.65	12.32
7102	85	305	11.08	0.00	0.00	37.07	42.65	0.00
7137	83	151	11.08	7.95	6.50	37.07	42.65	25.02
7139	83	151	11.08	41.46	1.20	37.07	42.65	4.62
7140	83	151	11.08	14.57	4.60	37.07	42.65	17.70
7142	85	135	11.08	4.48	1.20	37.07	42.65	4.62
7146	82	305	11.08	89.75	24.00	37.07	42.65	92.37
8172	83	151	11.08	5.60	3.60	37.07	42.65	13.86
8189	83	121	11.08	18.35	9.70	37.07	42.65	37.33
8193	83	151	11.08	23.00	5.30	37.07	42.65	20.40
8201	84	121	11.08	5.64	4.70	37.07	42.65	18.09
8401	88	302	11.08	0.49	0.10	37.07	42.65	0.38
8402	88	302	11.08	0.48	0.20	37.07	42.65	0.77
8403	88	262	11.08	2.52	0.20	37.07	42.65	0.77
8404	88	262	11.08	3.41	0.40	37.07	42.65	1.54
8405	88	275	11.08	12.39	0.60	37.07	42.65	2.31
9001	84	231	11.08	10.58	6.50	37.07	42.65	25.02
9002	84	231	11.08	0.31	1.80	37.07	42.65	6.93
9003	83	110	11.08	16.17	7.80	37.07	42.65	30.02
9006	83	121	11.08	217.68	142.30	37.07	42.65	547.70
9007	84	231	11.08	0.79	0.90	37.07	42.65	3.46
9010	84	135	11.08	1082.77	143.80	37.07	42.65	553.47
9013	84	121	11.08	31.15	34.60	37.07	42.65	133.17
9016	84	121	11.08	54.16	9.70	37.07	42.65	37.33
9020	83	249	11.08	24.43	5.90	37.07	42.65	22.71
9021	83	249	11.08	3.02	0.20	37.07	42.65	0.77
9022	83	249	11.08	569.83	16.20	37.07	42.65	62.35
9023	84	231	11.08	0.01	3.90	37.07	42.65	15.01
9024	84	135	11.08	7.85	1.70	37.07	42.65	6.54
9025	88	305	11.08	5.05	0.00	37.07	42.65	0.00
9026	88	152	11.08	4.13	1.00	37.07	42.65	3.85
9027	88	231	11.08	29.76	0.20	37.07	42.65	0.77
9028	88	181	11.08	57.00	0.80	37.07	42.65	3.08
9029	87	121	11.06	9.69	0.10	37.07	42.65	0.38
5030	68	231	11.08	20.82	0.10	37.07	42.65	0.38
9031	88	181	11.08	76.47	0.60	37.07	42.65	2.31
9034	87	302	11.08	5.57	0.40	37.07	42.65	1.54
9172	86	181	11.08	11.73	0.60	37.07	42.65	2.31
9175	86	135	11.08	18.67	1.90	37.07	42.65	7.31

```
Vehicle  Mod CID  Bag-2      Idle    Measured  CALINE     EMFAC 7F    Actual
 Number   Yr        Rate     Factor     Rate   Estimate  Estimate  Emissions
                 (g/mile) (g/hour)  (g/mile)  (grams)   (grams)    (grams)
===========================================================================
   9178 86  181    11.08      14.66      1.40     37.07      42.65      5.39
   9179 87  173    11.08      72.90      1.10     37.07      42.65      4.23
   9181 86  231    11.08     220.74      1.10     37.07      42.65      4.23
   9183 86  152    11.08       6.29      1.20     37.07      42.65      4.62
   9185 87  173    11.08      18.97      0.70     37.07      42.65      2.69
   9186 87  135    11.08       0.90      1.40     37.07      42.65      5.39
   9188 87  173    11.08      47.10      2.10     37.07      42.65      8.08
   9189 86  110    11.08       1.85      0.20     37.01      42.65      0.77
   9190 87  152    11.08     818.05     11.10     37.07      42.65     42.72
   9192 87  152    11.08       9.86      0.00     37.07      42.65      0.00
   9193 87  122    11.08       3.67      1.30     37.07      42.65      5.00
___________________________________________________________________________

..........................    Emissions Summary ---------------------------
Total Emissions Estimated by CALINE ----------- 17202.41   Grams
Total Emissions Estimated by EMFAC 7F ------------ 19787.61   Grams
Total Actual Emissions from Test Results ------ 19781.75   Grams

Average Prediction Factor (CALINE/Actual) --------- .8696101
Average Prediction Factor (EMFAC 7F/Actual) ---------- 1.000296

Mean CALINE estimated emission value -------------- 37.07417 Grams
Mean EMFAC 7F estimated emission value --------------- 42.64572 Grams
Mean ACTUAL emission value .......................    42.63309 Grams
Difference in means (CALINE vs Actual) -------------5.558926 Grams
Difference in means (EMFAC 7F vs Actual) ------------- 1.262665E-02 Grams

------------ Approximated NOVA results for W I N E vs Actual -----------

Sun of Squares for the Model .....................    14339.12
Sum of Squares for Error -------------------------- 7178309
Total Sum of Squares ------------------------------ 7192648
Psuedo R-Square Value for CALINE MODEL ------------ .199358  %
Psuedo Adjusted R-Square Value for CALINE Model --- 0  %

------------ Approximated ANOVA results for EMFAC 7F vs Actual -----------
Sum of Squares for the Model .....................    7.361946E-02
Sum of Squares for Error -------------------------- 7163966
Total Sum of Squares ------------------------------ 7163966
Psuedo R-Square Value for EMFAC 7F Model ------------- 1.027636E-06  %
Fsuedo Adjusted R-Square Value for EMFAC 7F Model ---- 0  %
```

Appendix E: Report 4 - Summary of All Vehicles on All Cycles

```
----------- Model Performance Summary Table for All Cycles ----------
--------------------------------------------------------------------
Cut-     Total     Total     Total     Caline   Caline   Emfac    Emfac
rate     CALINE    EMFAC 7F   Actual   R-Sqr     Adj.     R-Sqr    Adj
mph/s   Estimate  Estimate  Emissions           R-Sqr             R-Sqr
--------------------------------------------------------------------


Results for ----------- FEDERAL TEST PROCEDURE, BAG 1
0.60    21073.65  14462.11  34216.82   6.3       5.3      12.5      9.5

Results for ----------- FEDERAL TEST PROCEDURE, BAG 2
0.60    19761.76  19787.61  19781.75   0.0       0.0      0.0       0.0

Results for ----------- FEDERAL TEST PROCEDURE, BAG 3
0.60    21073.65  14462.11  15846.13   2.1       1.0      0.4       0.0

Results for ----------- HIGHWAY FUEL ECONOMY TEST
0.60    20990.56  20299.98  23847.87   0.1       0.0      0.6       0.0

Results for ----------- HIGH SPEED TEST CYCLE # 1
0.60      166.21    128.53    106.00   25.8      6.3      36.9      0.0

Results for ----------- HIGH SPEED TEST CYCLE # 2
0.60      213.15    155.18    113.76   36.3      19.5     41.9      0.0

Results for ----------- HIGH SPEED TEST CYCLE # 3
0.60      638.85    550.83    800.12   3.1       0.0      15.7      0.0

Results for ----------- HIGH SPEED TEST CYCLE # 4
0.60      896.95   1455.59   2639.70   9.2       2.0      12.0      0.0

Results for ----------- LOW SPEED TEST CYCLE # 1
0.60     3570.01   4486.08   3668.17   0.0       0.0      3.9       0.0

Results for ----------- LOW SPEED TEST CYCLE # 2
0.60     3348.82   5091.27   5711.34   2.5       0.4      1.0       0.0

Results for ----------- LOW SPEED TEST CYCLE # 3
0.60     3204.72   5022.66   8609.21   5.4       3.3      2.8       0.0

Results for ----------- NEW YORK CITY CYCLE
0.60    12621.31  13537.14  13550.23   0.1       0.0      0.1       0.0

Results for ----------- SPEED CORRECTION FACTOR CYCLE 12
0.60     7723.28   7622.07   7726.73   0.0       0.0      0.0       0.0
```

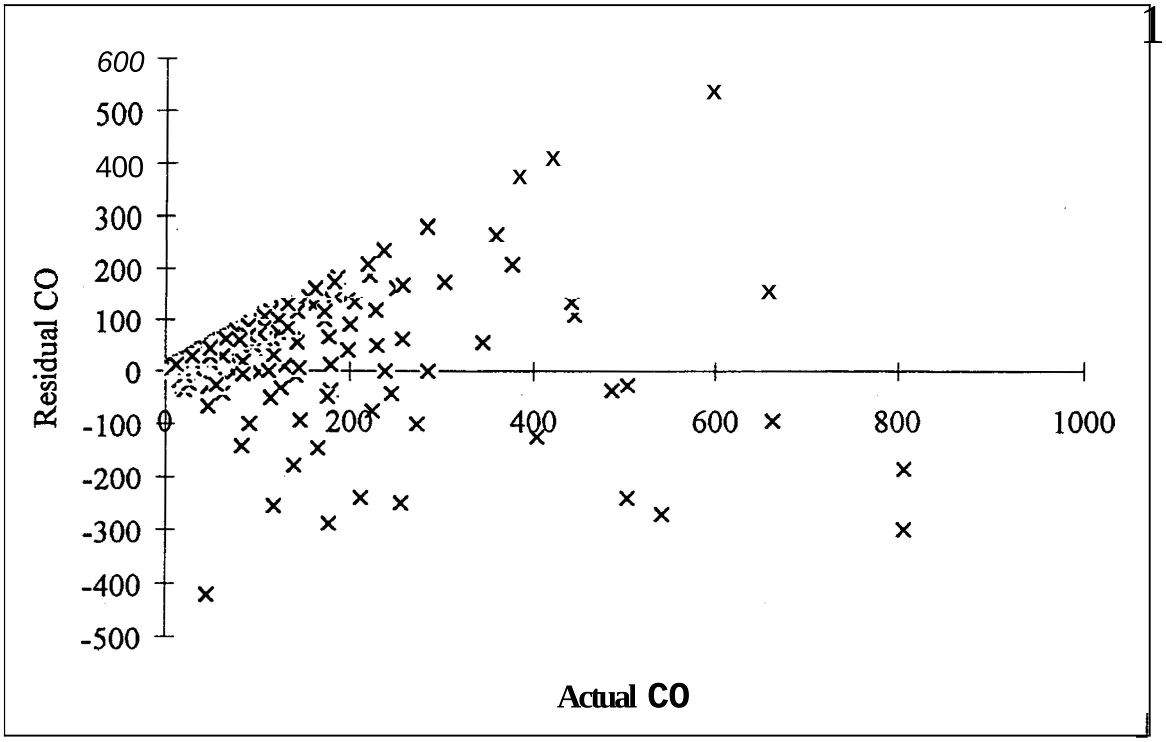
```
Cut-     Total      Total      Total     Caline    Caline    Emfac     Emfac
rate     CALINE     EMFAC 7F    Actual    R-Sqr     Adj.      R-Sqr     Adj.
mph/s    Estimate   Estimate   Emissions            R-Sqr               R-Sqr
.................................................................
Results for ----------- SPEED CORRECTION FACTOR CYCLE 36
0.60     30955.69   29084.27   29548.68    0.0       0.0       0.4       0.0
```

```
----------- Model Performance Summary Table for All Cycles ----------
--------------------------------------------------------------------
Cut-     CALINE    EMFAC 7F    Actual    SST        SS        SST        SS
rate      Mean      Mean       Mean    CALINE     MODEL     EMFAC 7F    MODEL
mph/s   Emission  Emission   Emission             CALINE               EMFAC 7F
--------------------------------------------------------------------

Results for ----------- FEDERAL TEST PROCEDURE, BAG 1
0.60     45.42      31.17      73.74     5924777    372289   6799840    047563

Results for ----------- FEDERAL TEST PROCEDURE, BAG 2
0.60     42.59      42.65      42.63     7163982         1   7163966         0

Results for ----------- FEDERAL TEST PROCEDURE, BAG 3
0.60     45.42      31.17      34.15     2866496     58895   2746822     10635

Results for ----------- HIGHWAY FUEL ECONOMY TEST
0.60     45.24      43.75      51.40    17359076     17596  17869576    115720

Results for ----------- HIGH SPEED TEST CYCLE # 1
0.60      6.65       5.14       4.24         562       145       998       368

Results for ----------- HIGH SPEED TEST CYCLE # 2
0.60      8.53       6.21       4.55        1089       395      1476       619

Results for ----------- HIGH SPEED TEST CYCLE # 3
0.60      9.26       7.98      11.60       11975       377     20724      3259

Results for ----------- HIGH SPEED TEST CYCLE # 4
0.60     13.00      21.10      38.26      477196     44017    557181     67050

Results for ----------- LOW SPEED TEST CYCLE # 1
0.60     15.13      19.01      15.54      298746        41    311607     12305

Results for ----------- LOW SPEED TEST CYCLE # 2
0.60     14.17      21.57      24.20      928726     23651    879638      8540

Results for ----------- LOW SPEED TEST CYCLE # 3
0.60     13.58      21.28      36.48     2304760    123765   2148155     59860
```

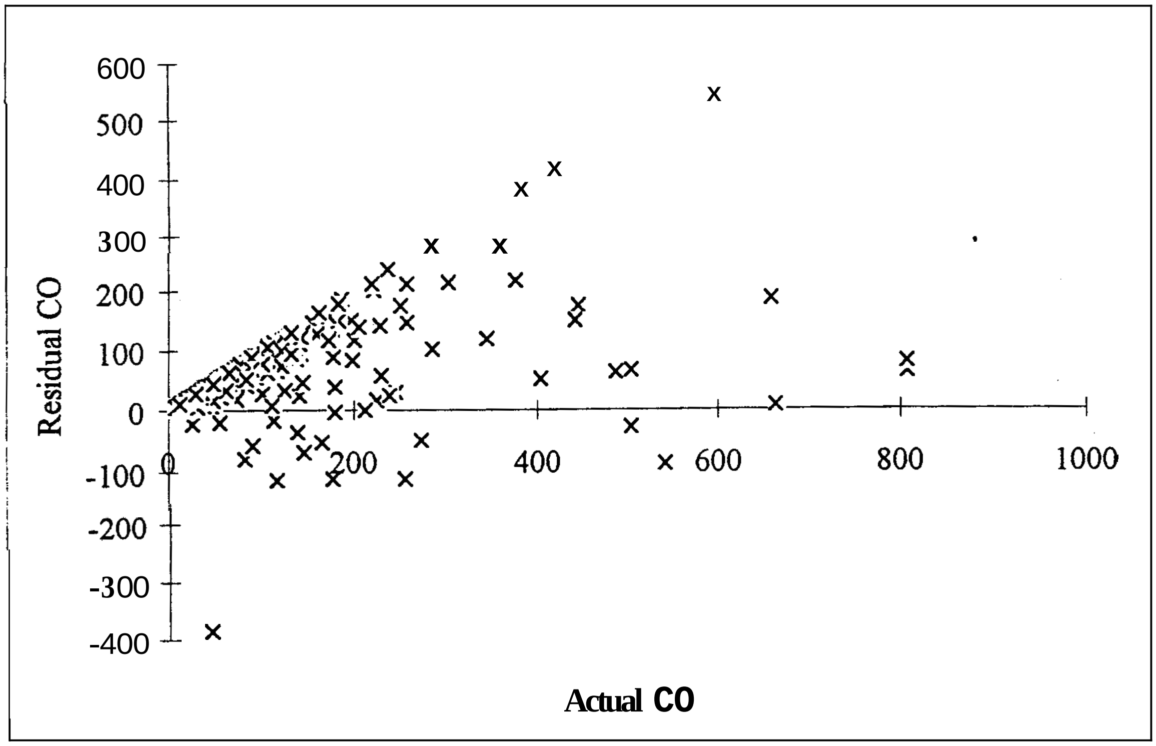
```
Cut-    CALINE    EMFAC 7F    Actual   SST        SS        SST        SS
rate     Mean      Mean       Mean   CALINE     MODEL    EMFAC 7F    MODEL
mph/s  Emission  Emission  Emission             CALINE             EMFAC 7F
--------------------------------------------------------------------------

Results for ----------- NEW YORK CITY CYCLE
0.60    27.20     29.17     29.20    2147480      1860   2138125      1563

Results for ----------- SPEED CORRECTION FACTOR CYCLE 12
0.60    16.64     16.43     16.65     848549         0    550285        90

Results for ----------- SPEED CORRECTION FACTOR CYCLE 36
0.60    66.71     62.68     63.68   18201570      4266  18527850     77270
```

Appendix F: Residual Plots for CALINE 4 and EMFAC 7F Algorithms

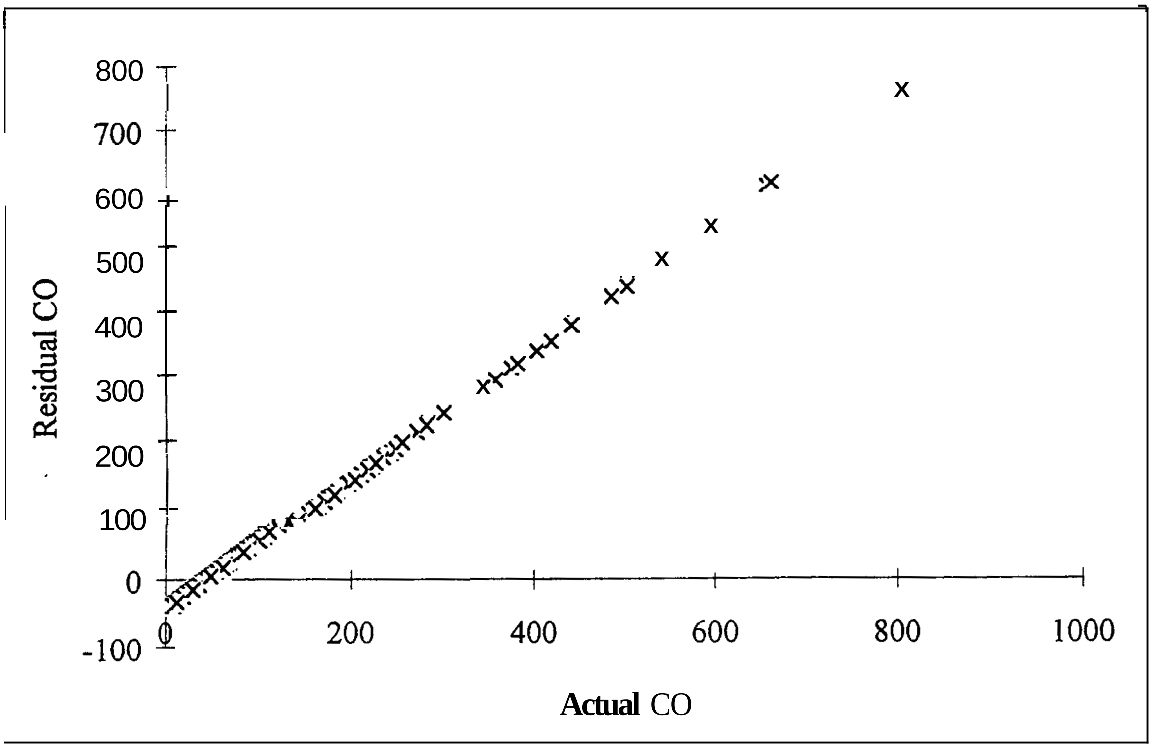
1) Federal Test Procedure Bag 1; CALINE 4 - Individual Vehicle Values versus Residuals (grams)



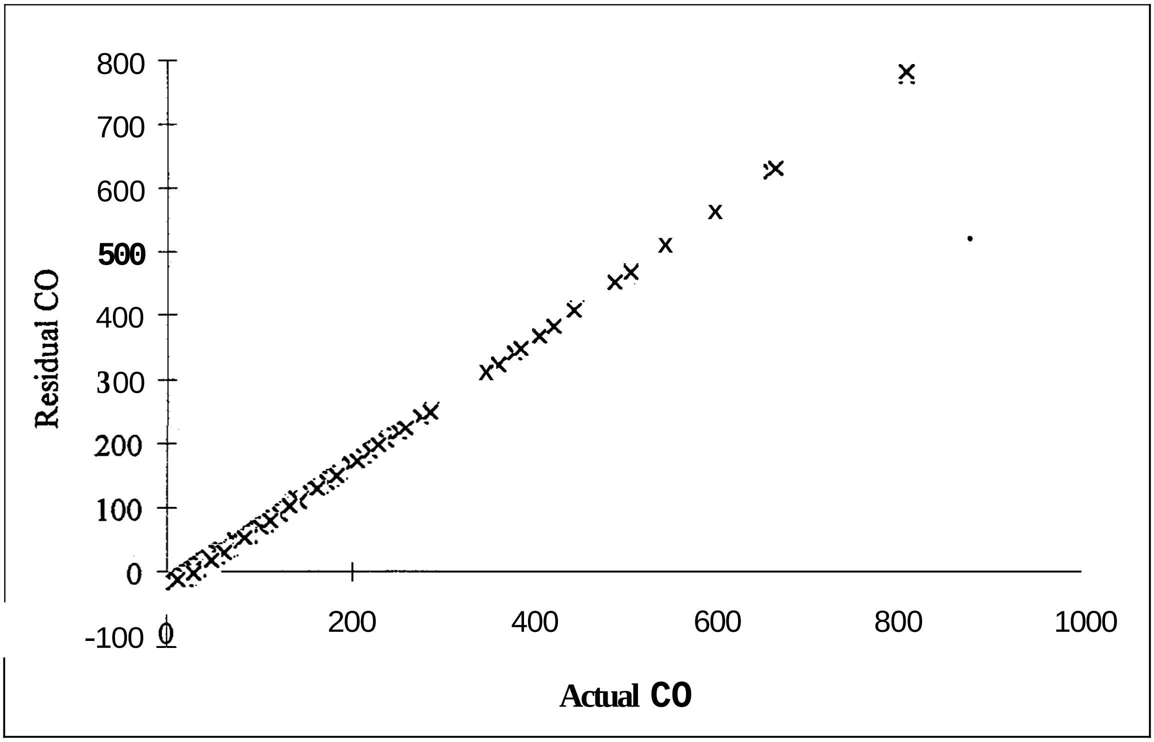
2) Federal Test Procedure Bag I; EMFAC 7F - Individual Vehicle Values versus Residuals (Pam)



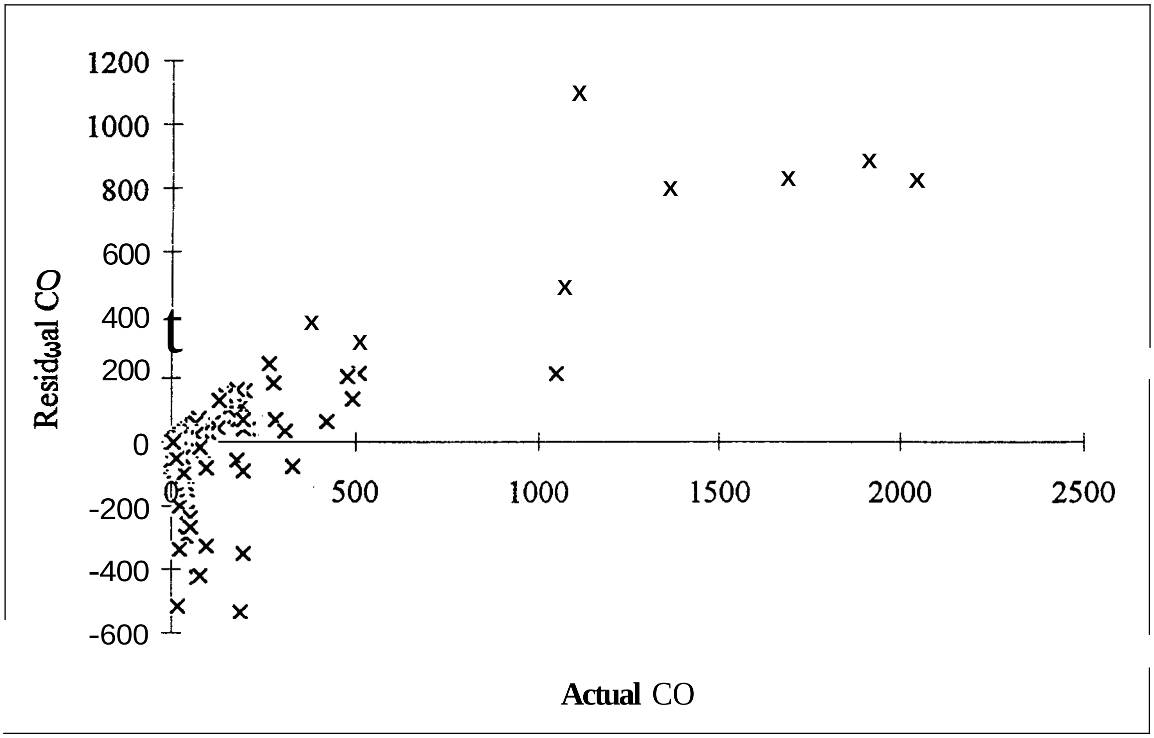
3) Federal Test Procedure Bag I; CALINE 4 - Average Vehicle Values versus Residuals (grams)



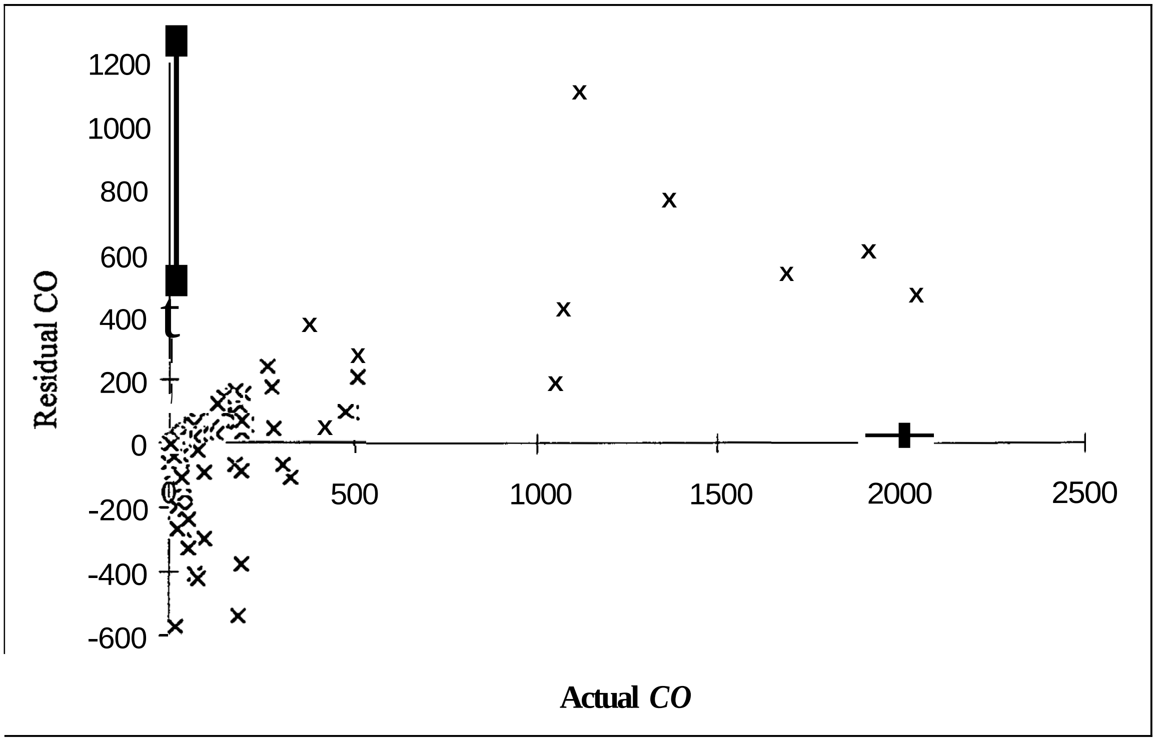
4) Federal Test Procedure Bag I; EMFAC 7F - Average Vehicle Values versus Residuals (grams)



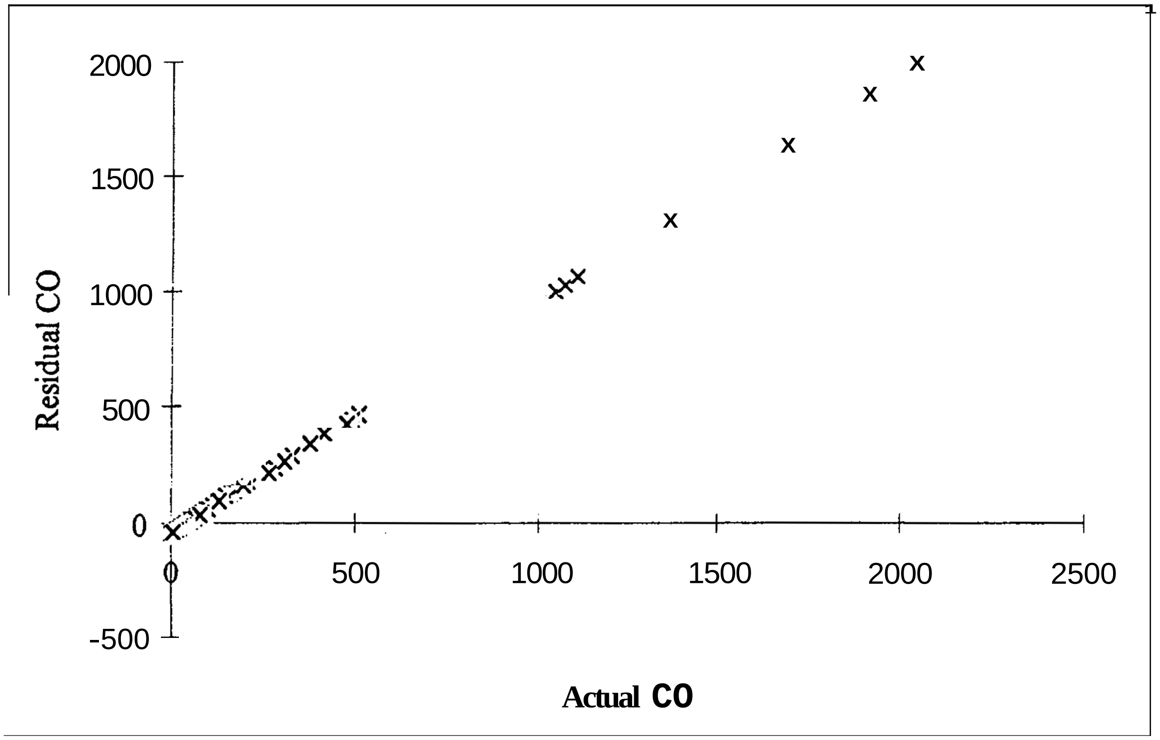
5) Highway Fuel Economy Test; CLINE 4 - Individual Vehicle Values versus Residuals (grams)



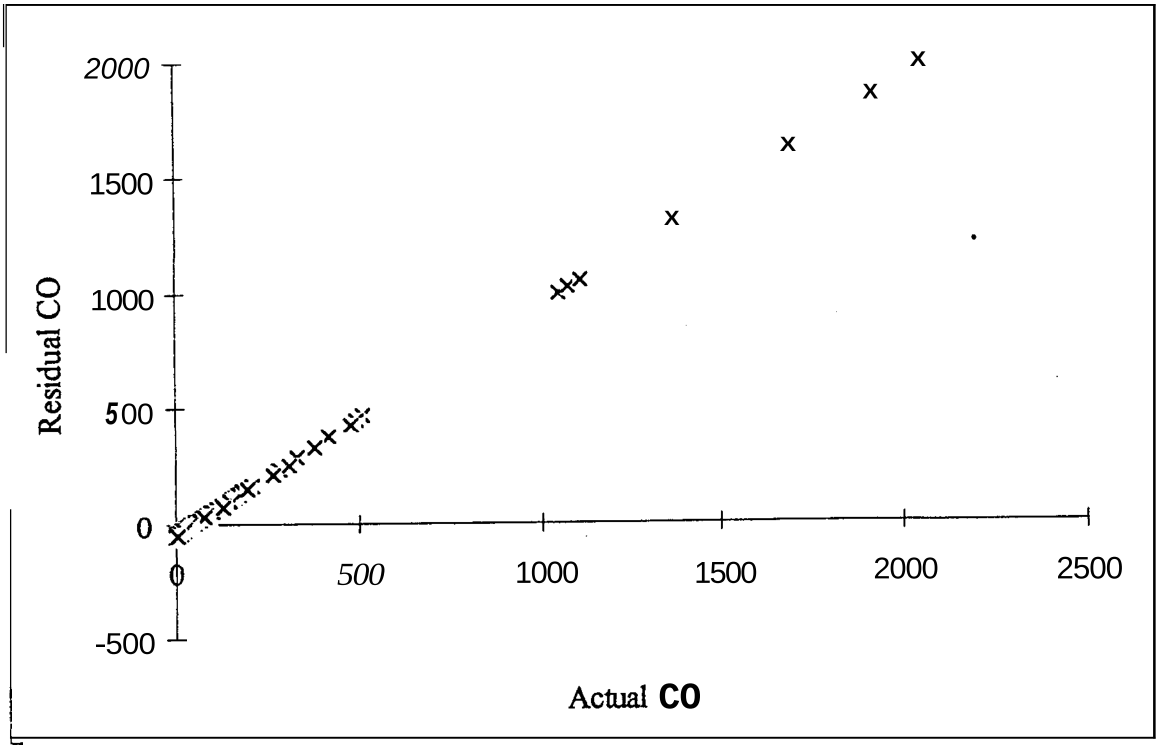
6) Highway Fuel Economy Test; EMFAC 7F - Individual Vehicle Values versus Residuals (grams)



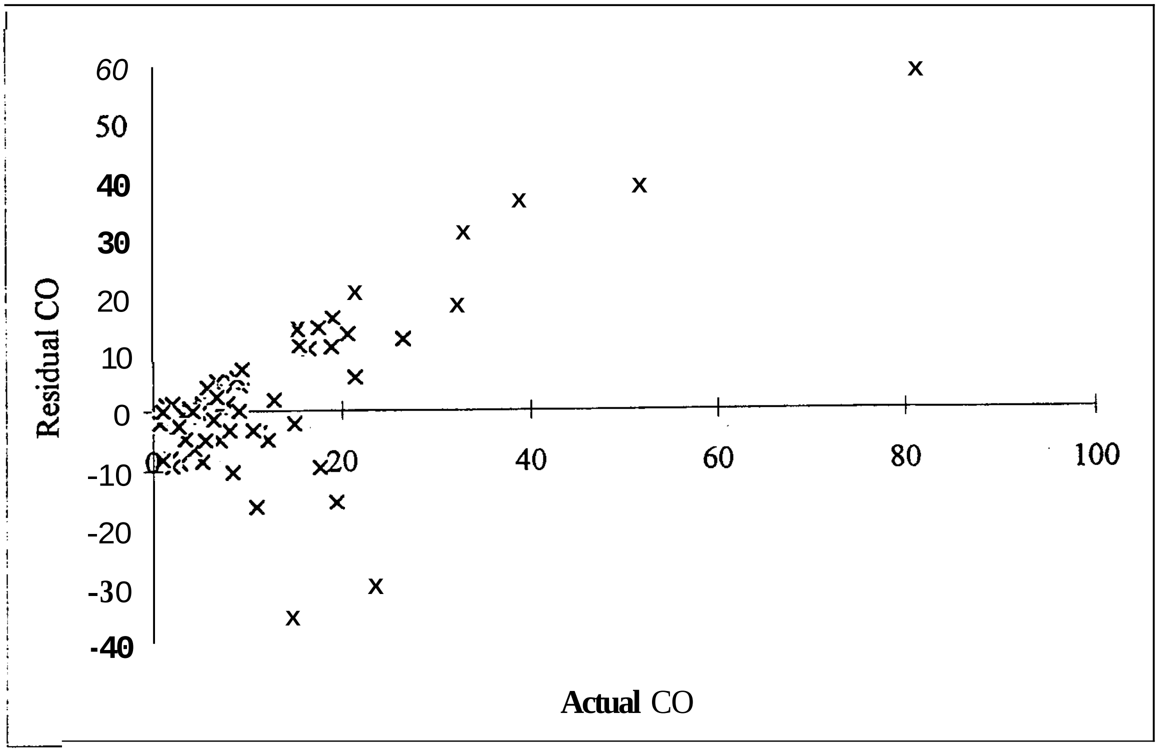
7) Highway Fuel Economy Test; CALINE 4-Average Vehicle Values versus Residuals (grams)



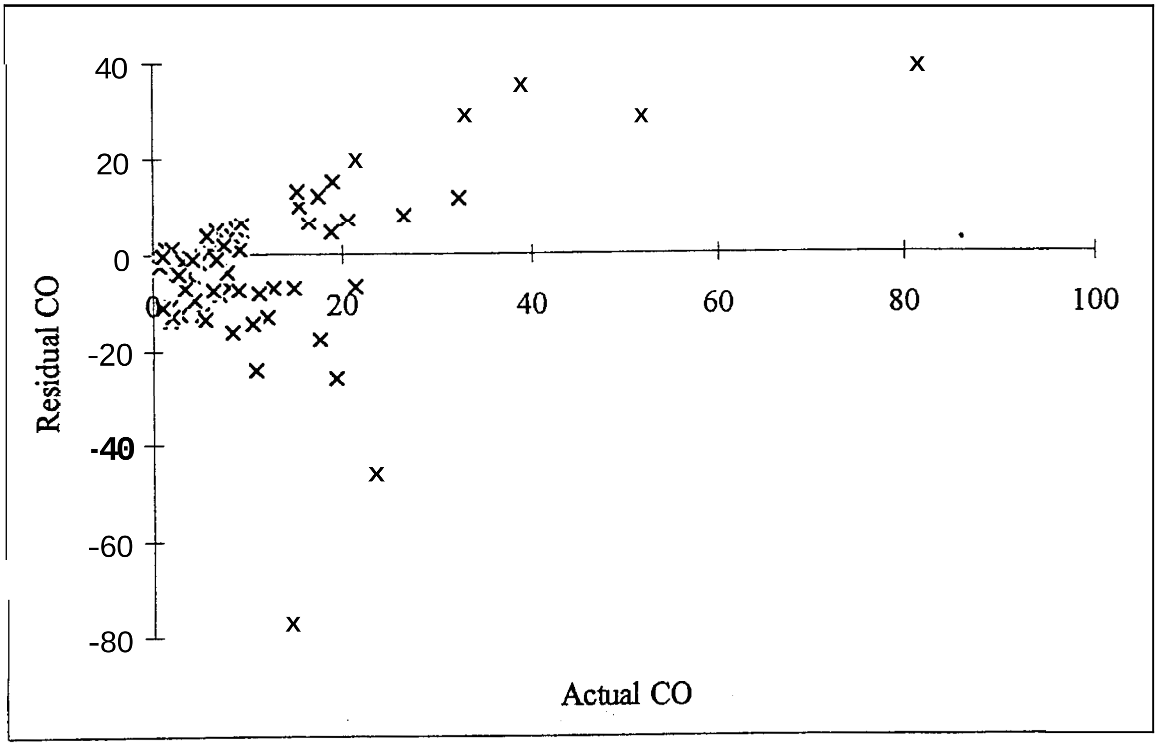
8) Highway Fuel Economy Test; EMFAC 7F - Average Vehicle Values versus Residuals (grams)



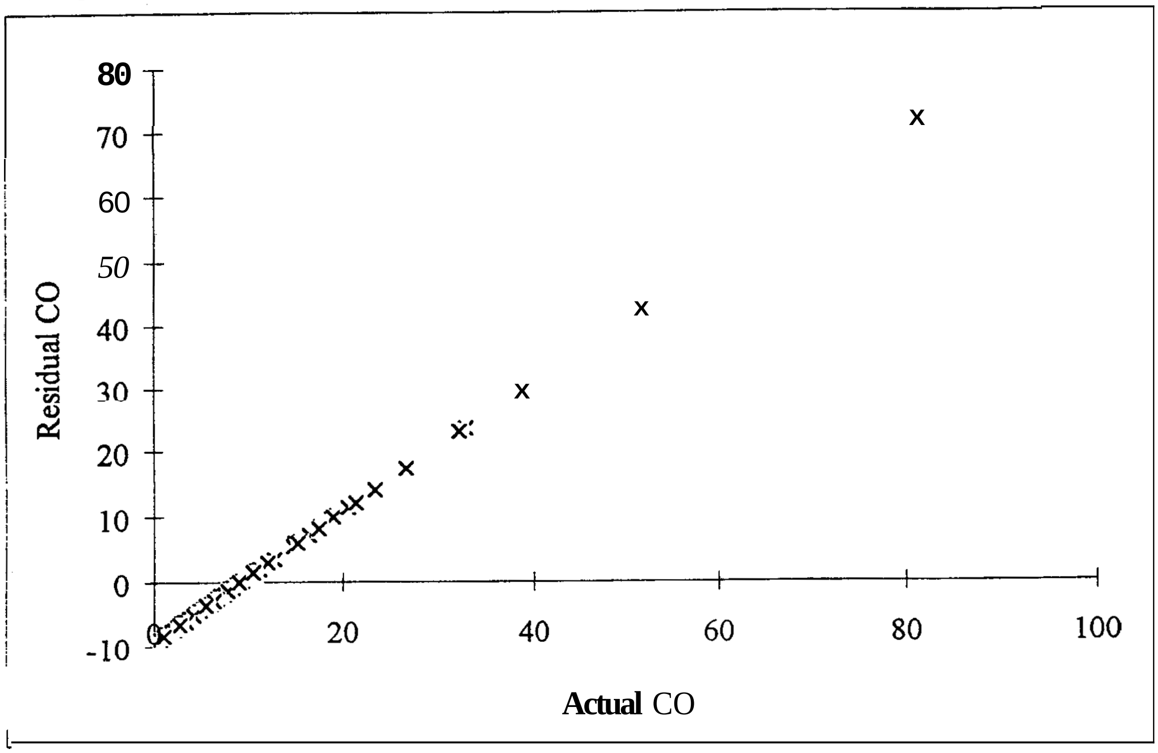
9) High Speed Test Cycle #3; CALINE 4 - Individual Vehicle Values versus Residuals (grams)



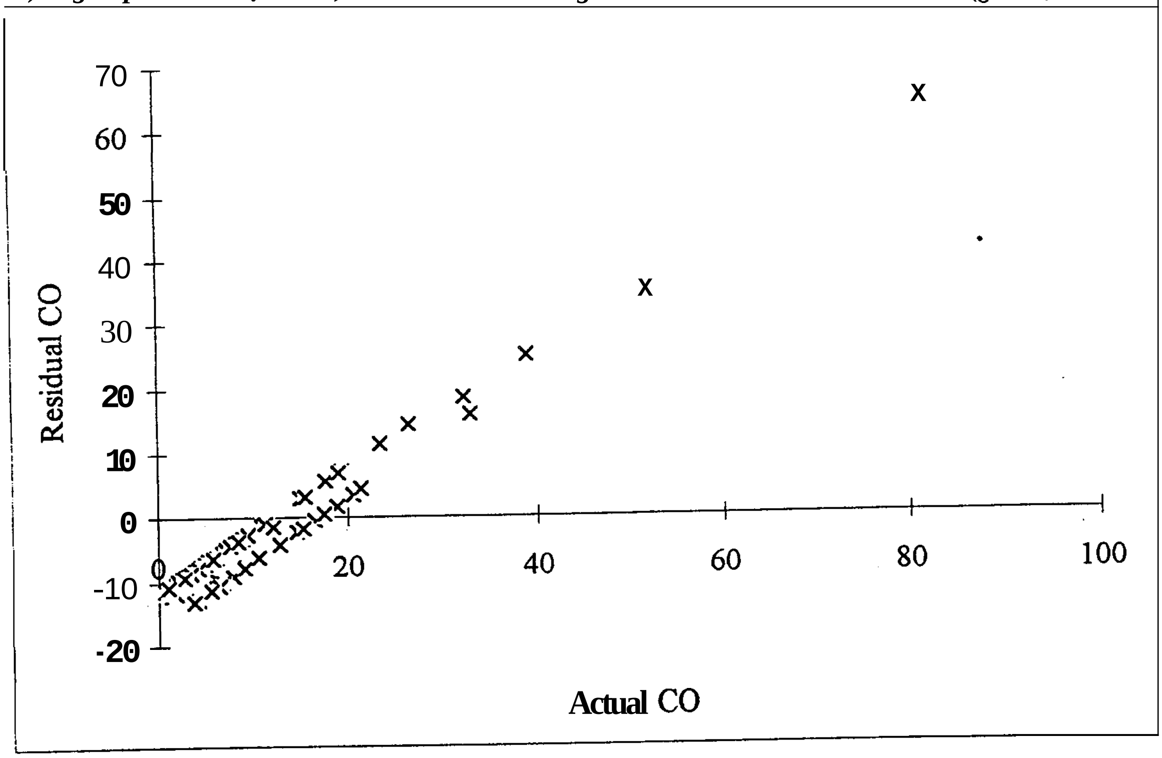
10) High Speed Test Cycle #3; EMFAC 7F - Individual Vehicle Values versus Residuals (grams)



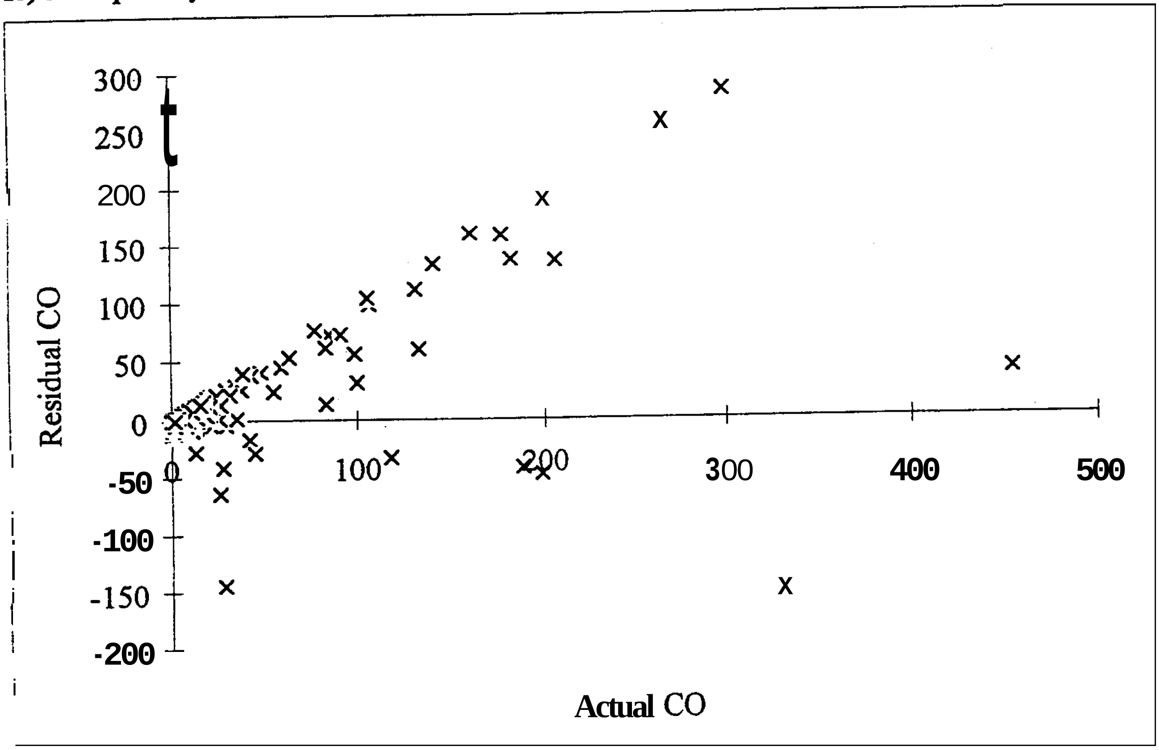
11) High Speed Test Cycle #3; CALINE 4 - Average Vehicle Values versus Residuals (grams)



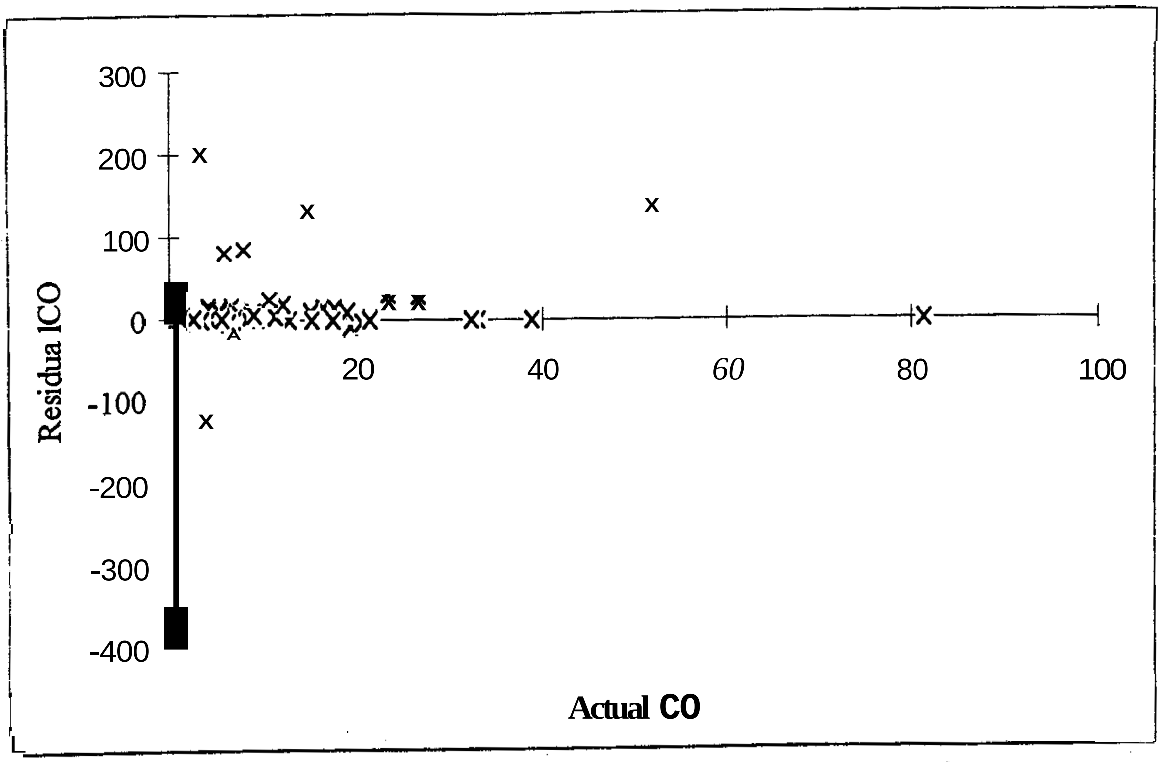
12) High Speed Test Cycle #3; EMFAC 7F- Average Vehicle Values versus Residuals (grams)



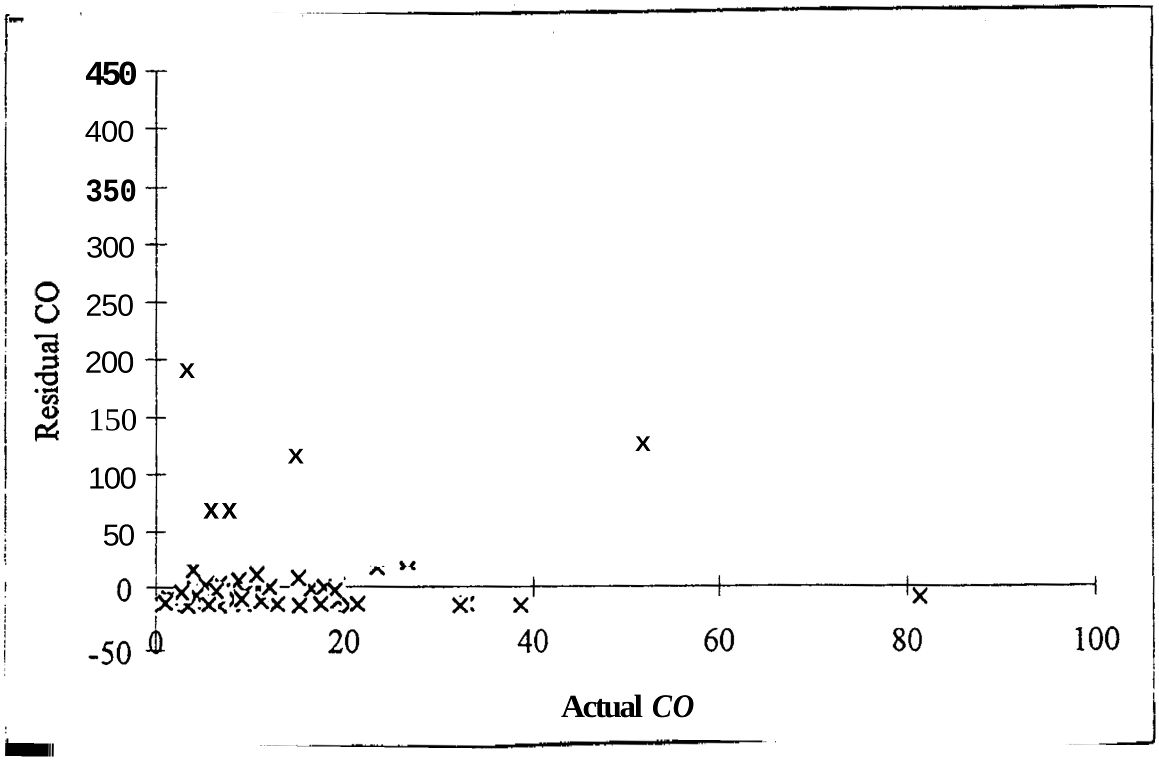
13) Low Speed Cycle #1; CALINE 4 - Individual Vehicle Values versus Residuals (grams)



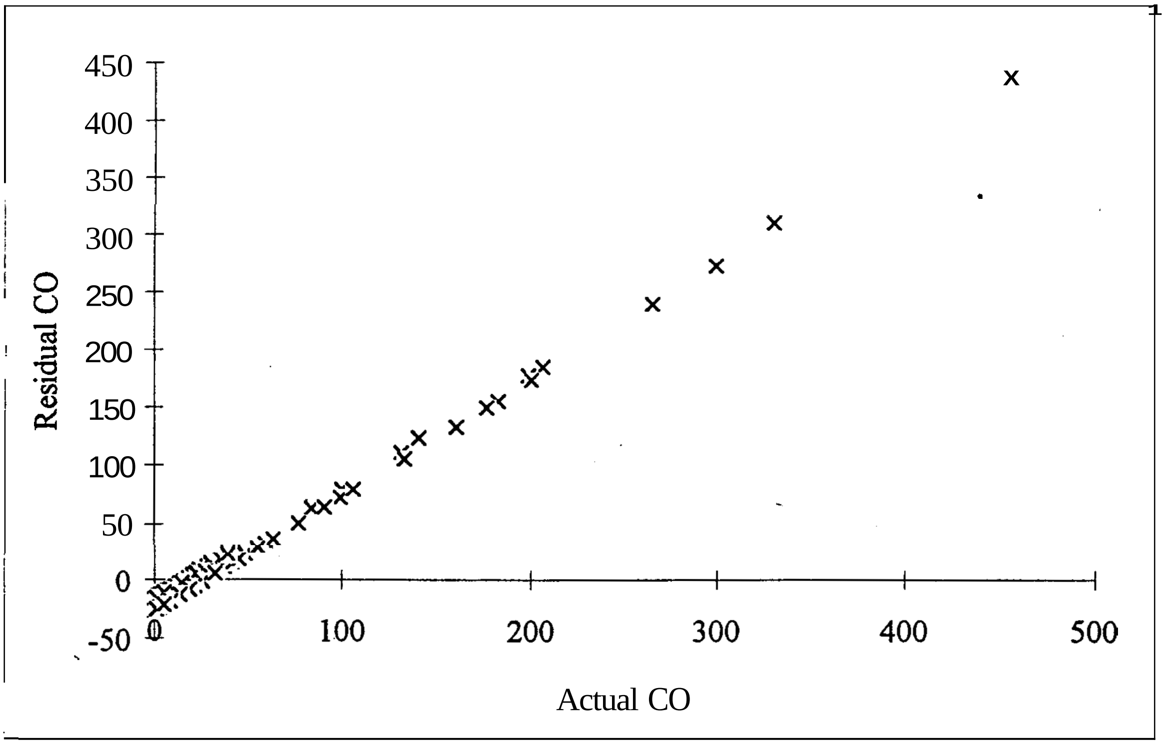
14) Low Speed Cycle #1; EMFAC 7F - Individual Vehicle Values versus Residuals (gram)



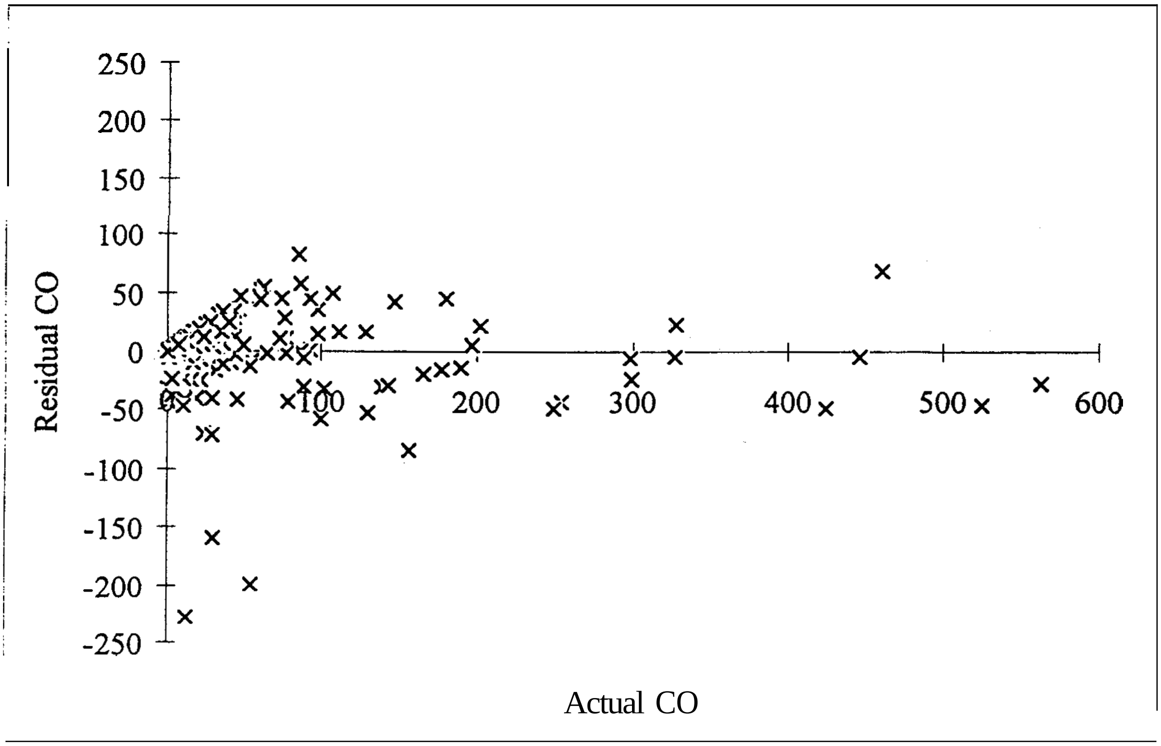
15) Low Speed Cycle #1; CALINE 4 - Average Vehicle Values versus Residuals (grams)



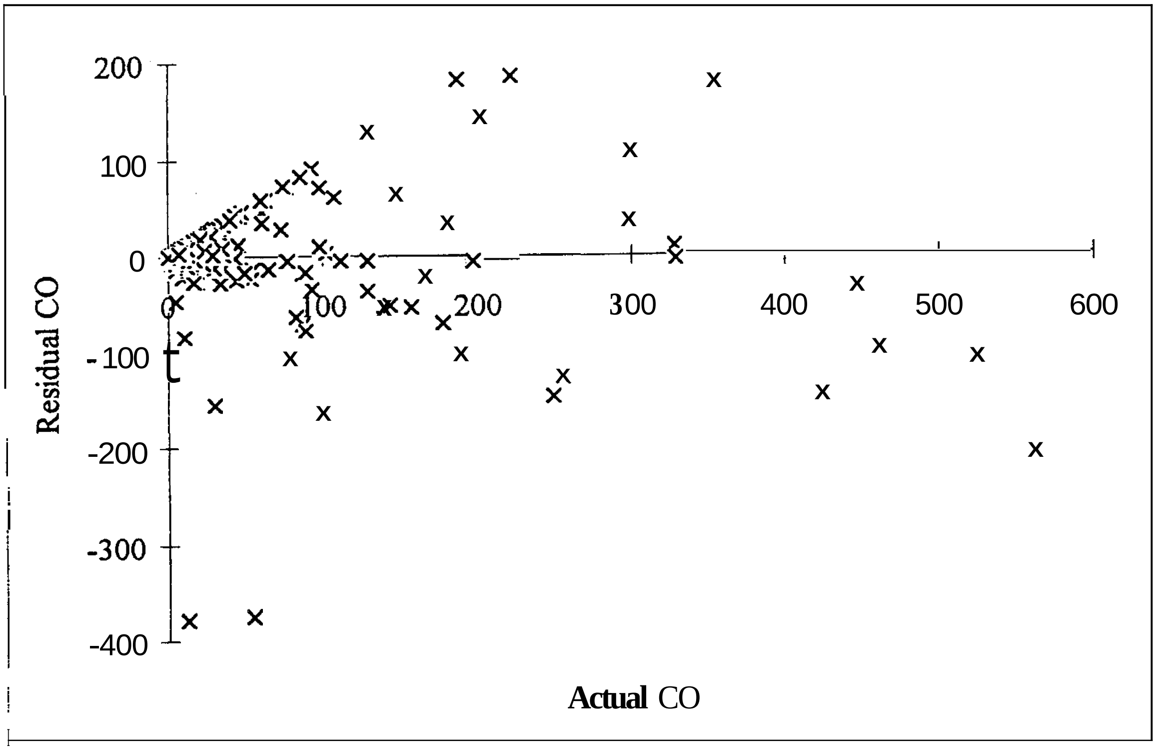
16) Low Speed Cycle #1; EMFAC 7F - Average Vehicle Values versus Residuals (grams)



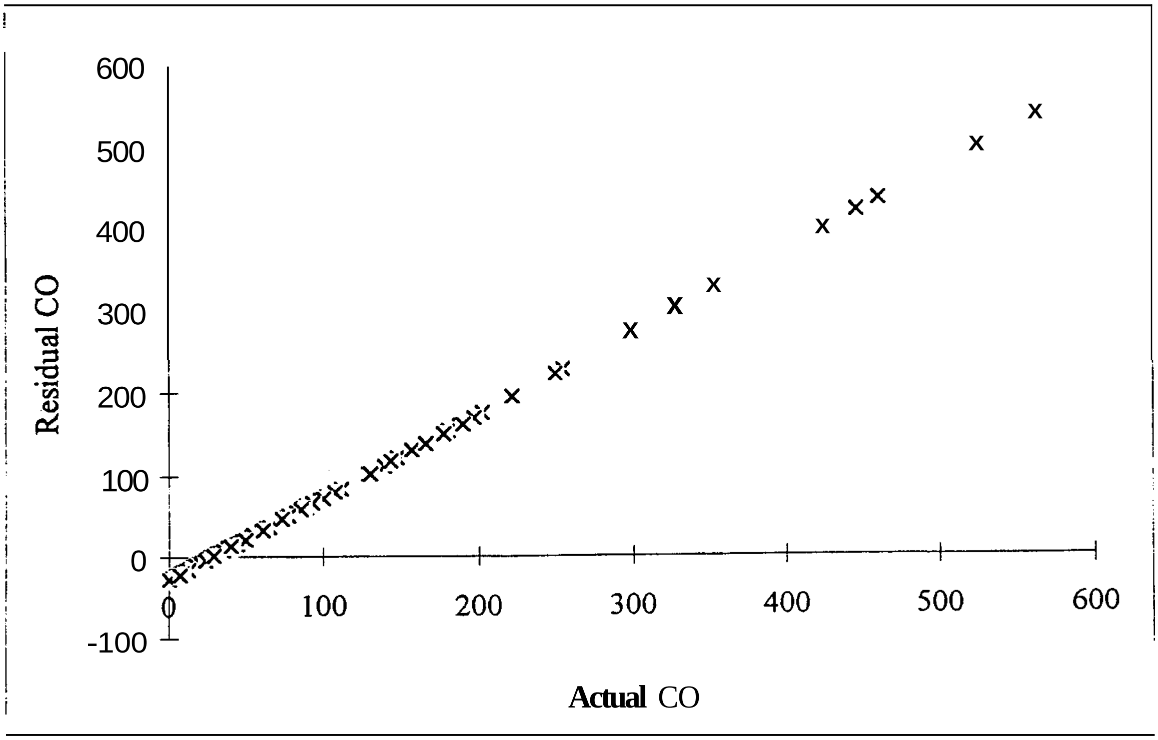
17) New York City Cycle; CLINE4 - Individual Vehicle Values versus Residuals (grams)



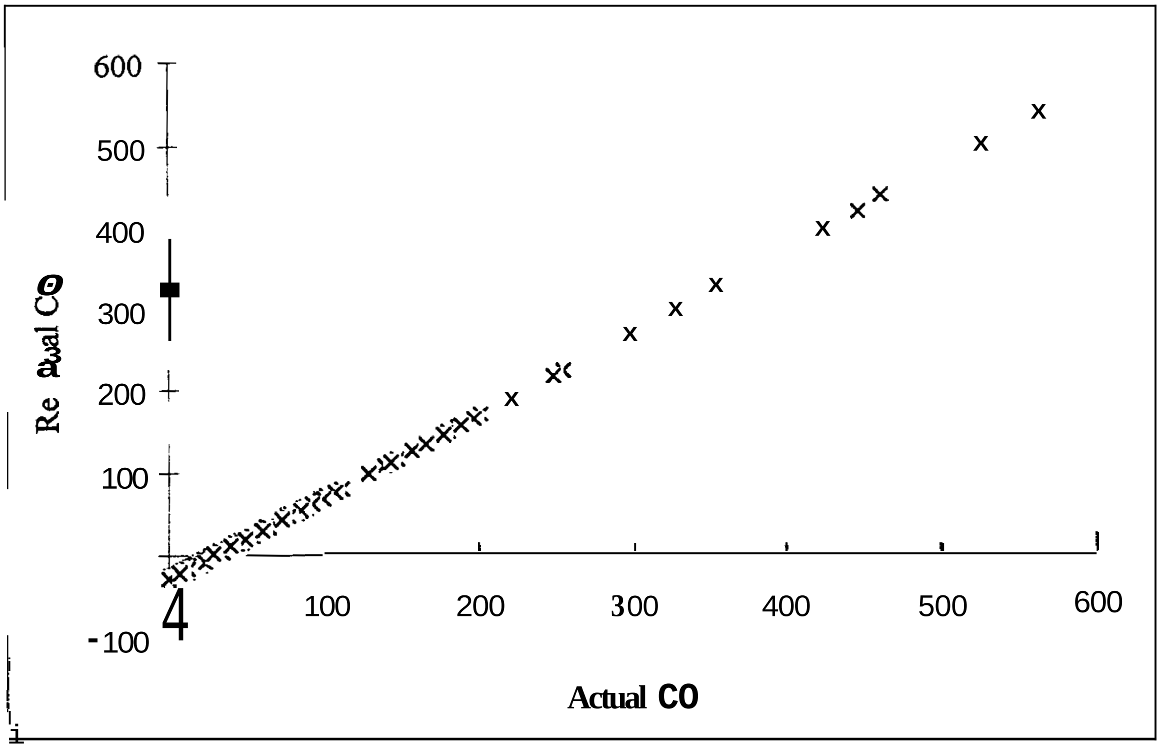
18) New York City Cycle; EMFAC 7F- Individual Vehicle Values versus Residuals (grams)



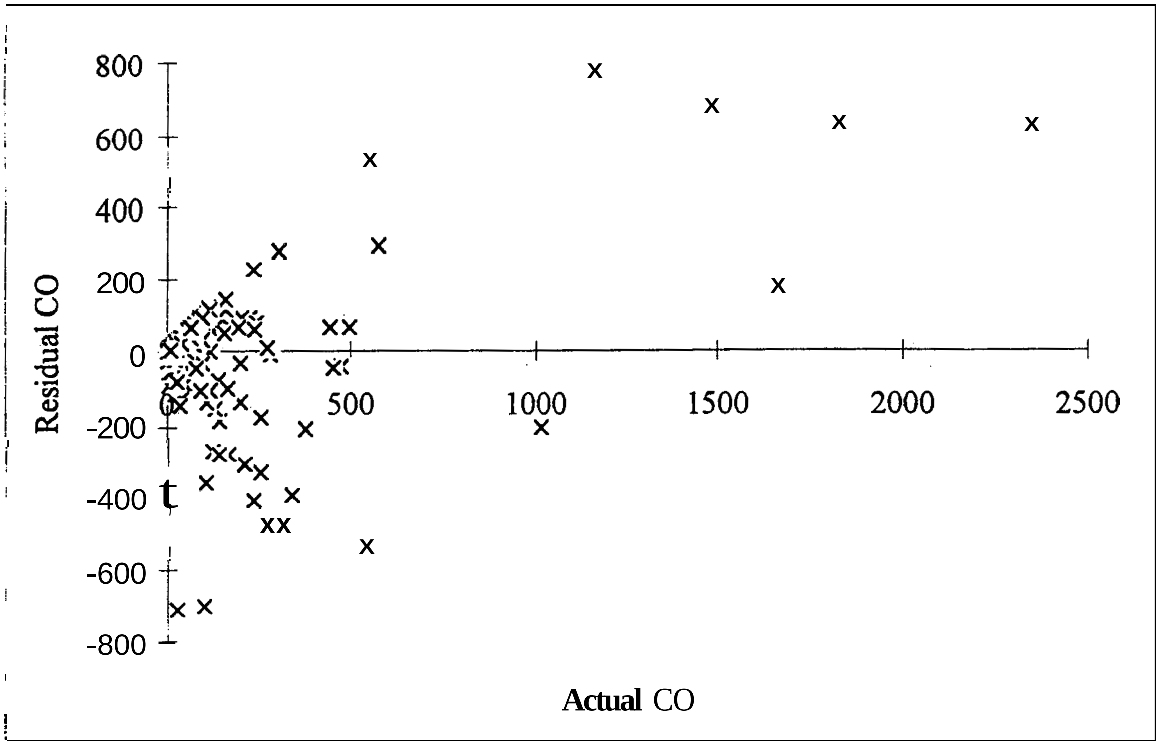
19) New York City Cycle; CLINE4 -Average Vehicle Values versus Residuals (grams)



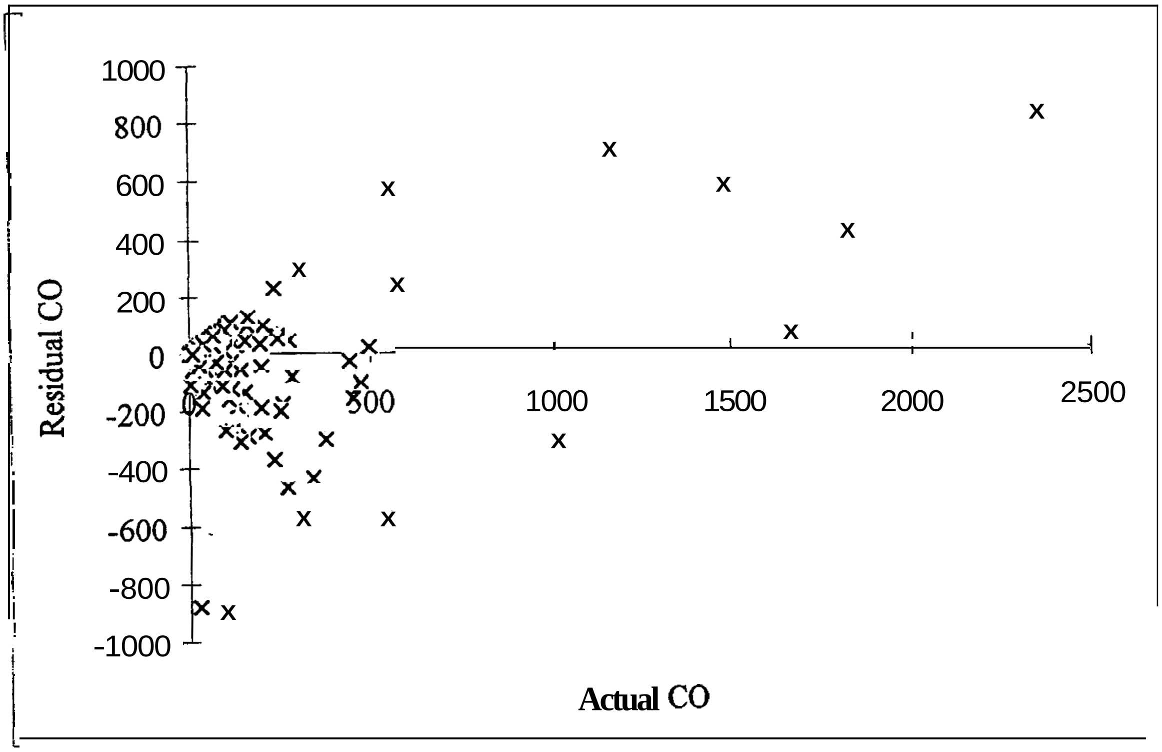
20) New York City Cycle; EMFAC 7F - Average Vehicle Values versus Residuals (gram)



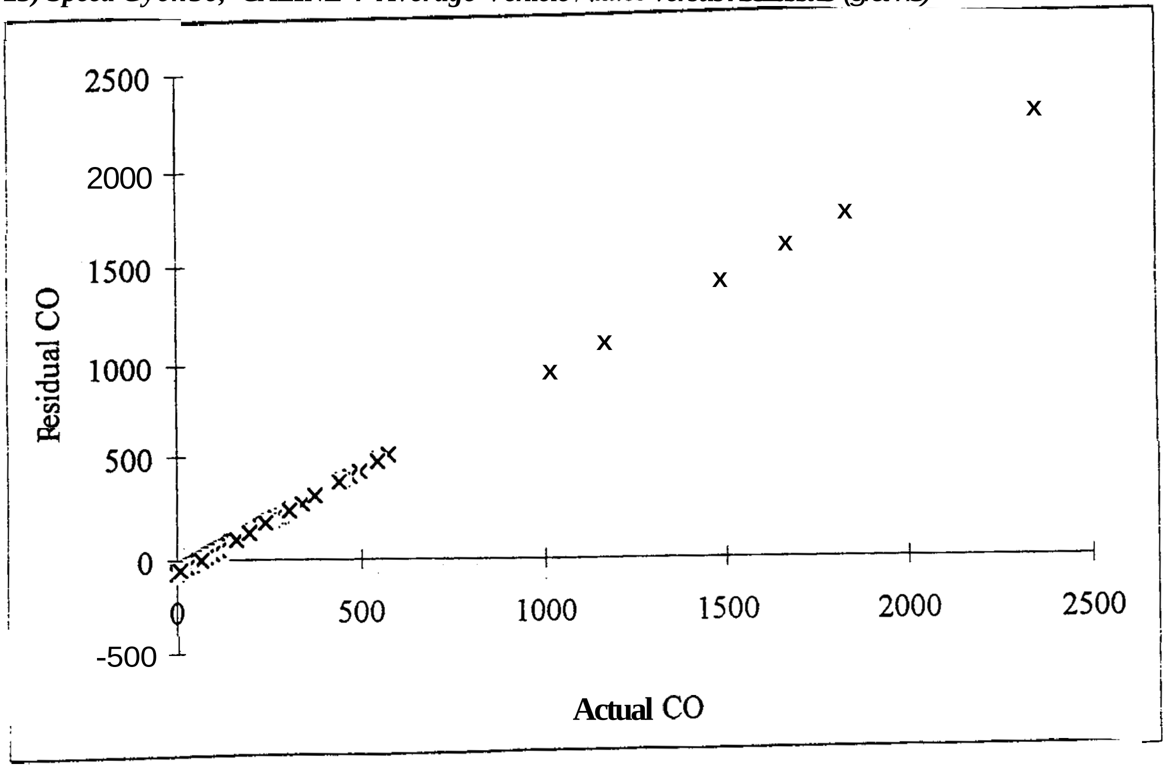
21) Speed Cycle 36; CALINE 4 - Individual Vehicle Values versus Residuals ('grams)



22) Speed Cycle 36; EMFAC 7F - Individual Vehicle Values versus Residuals (grams)



23) Speed Cycle 36; CALINE 4 - Average Vehicle Values versus Residuals (grams)



24) Speed Cyck 36; EMFAC 7F - Average Vehicle Values versus Residuals (grams)