Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/TX-80/7+218-5F		

4. Title and Subtitle
Analytical and Experimental Assessment of Highway Impact on Air Quality: Data Analysis and Model Evaluation

5. Report Date
January 21, 1980

6. Performing Organization Code

7. Author(s)
J. A. Bullin, J. C. Polasek, N. J. Green

8. Performing Organization Report No.
Research Report 218-5F

9. Performing Organization Name and Address
Chemical Engineering Department and
Texas Transportation Institute
The Texas A&M University System
College Station, Texas 77843

10. Work Unit No. (TRAIS)

11. Contract or Grant No.
2-8-75-218

12. Sponsoring Agency Name and Address
Texas State Department of Highways and Public Transportation; Transportation Planning Division
P. O. Box 5051
Austin, Texas 78763

13. Type of Report and Period Covered
Final Report -
September, 1974
January 21, 1980

14. Sponsoring Agency Code

15. Supplementary Notes

Work done in cooperation with FHWA, DOT

16. Abstract
Air pollution data were collected at six sites in Texas. The data have been screened, reduced, and put into 5-minute and 15-minute data records to form a large data base. These data are arranged for easy use for model development or evaluation.

In this report, the development of a new pollutant dispersion model, TRAPS IIM is described. This new model, along with several popular models, is compared to experimental data. The advantages and disadvantages of the TRAP IIM model are discussed.

A statistical treatment of instantaneous data from several instruments are analyzed. Power spectra, cross correlation, and probability densities of two data cases are discussed and interpreted.

This report and the experimental data on magnetic tapes are available from the Texas State Department of Highways and Public Transportation and NTIS. They are also available at modest costs from Dr. Jerry A. Bullin, Chemical Engineering Department, Texas A&M University, College Station, Texas 77843, Phone 713/845-3361.

17. Key Words	18. Distribution Statement
Computer controlled sampling; carbon monoxide, total hydrocarbons and nitrogen oxides from roadways	No Restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified		

Form DOT F 1700.7 (8-72)

Final Report

on

ANALYTICAL AND EXPERIMENTAL ASSESSMENT OF HIGHWAY IMPACT ON AIR QUALITY: DATA ANALYSIS AND MODEL EVALUATION

by

J. A. Bullin
J. C. Polasek
N. J. Green

Submitted to

File D-8 P
State Department of Highways
and Public Transportation

Research Report 218-5F

Research Study No. 2-8-75-218

Sponsored by

State Department of Highways and Public Transportation
in cooperation with the
U. S. Department of Transportation
Federal Highway Administration

CHEMICAL ENGINEERING DEPARTMENT
and
TEXAS TRANSPORTATION INSTITUTE
College Station, Texas 77843

January 21, 1980

TABLE OF CONTENTS

LIST OF FIGURES

IMPLEMENTATION

Dispersion data for several roadway pollutants have been collected at six different sites in Texas. The data have been arranged into 5-minute and 15-minute average records to form a large data base. The data base has been arranged into a meaningful format for use in model development. A model for pollutant dispersion from roadways has been developed. This improved dispersion model was compared to several other popular models and to the experimental data.

DISCLAIMER

SUMMARY

This project was initiated in order to establish a wide ranged data base for the purpose of validating existing roadway air quality models and to construct improved models. Data were collected at a variety of sites in the State of Texas. These data have been screened, bad data removed, and the remainder of the data reduced to a form useful to roadway pollution personnel.

In this report, several of the existing roadway air quality models, are evaluated. The construction of a new model TRAPS IIM is also described. This new model, along with the previously examined models, is compared with the data from the Texas Data Base for approximately 2200 points. The comparative computer time and memory required are examined. The advantages and disadvantages of the new model are discussed.

A brief statistical analysis of two data cases from the data base are also discussed. The instantaneous data from several instruments were analyzed using power spectra, cross-correlation, auto correlation, and probability densities, and the results interpreted.

CHAPTER I

INTRODUCTION

Project 218 was established with two major goals. The primary goal was the development of a data base for use in the validation and calibration of roadway air quality models for use in the state of Texas. A second related goal was the construction of new and improved models for the same purpose.

Previous data collection programs in other states have resulted in contradictory findings concerning the accuracy of various models. In addition, the state of Texas is geographically large and has a wide variety of climatological regions. Hence, Project 218 had to be designed to accumulate a larger data base than any single study undertaken previously. It was hoped that by collecting more data at more sites using the same procedures, many contradictions from previous studies could be resolved.

In conducting the work, air quality measurements were made at six sites representing at-grade, elevated and cut roadbed configurations. The state was divided into four climatological regions and at least one site was selected in each region. The City of Houston was selected to represent the "coastal plain" region of Texas and two sites were monitored there. Dallas is located in the "inland plain" region and also supplied two sites. The "hill country" region was represented by a site in San Antonio, and a site in El Paso was used to examine dispersion in "mountainous" terrain.

Measurements at each of the sites consisted of carbon monoxide concentration at ten downwind and two upwind locations, vehicle length, count, and speed by land, and detailed wind speed, wind direction, temperature, relative humidity, and solar radiation between five and 100 foot heights. The general instrumentation layout for the instruments is presented in Figure 1. Nitrogen oxides concentration at four downwind and one upwind station were also measured at selected sites. The instruments were monitored on a continuous cycle at intervals of 0.01 seconds for radars to 60 seconds for thermometers. Most meteorological and concentration instruments had cycle intervals of 2 to 15 seconds.

The instruments were interfaced to a Data General NOVA 1200 minicomputer, allowing effectively simultaneous recording of all instrument outputs. The resulting data were logged on magnetic cassette and later transferred to standard nine track tape.

Effort was also expended to develop a superior air quality model for use in the state of Texas. Typically, in previous data collection programs a data base was collected and used to construct an air quality model. It was then shown that the model fit the data base better than previous models. This was not a fair test, since the model was being compared to the data used to develop it. In order to avoid this problem, Project 218 personnel gathered several data bases, used one of the data bases to construct a model, and then compared the model to others using the rest of the independent data bases. The development of this model is described in some detail in Report 218-1 (Bullin and Polasek, 1976). The data collection methods used at the two sites in Houston are also detailed in this report. The information covered includes the methods used to acquire traffic information, information formats on tape, and

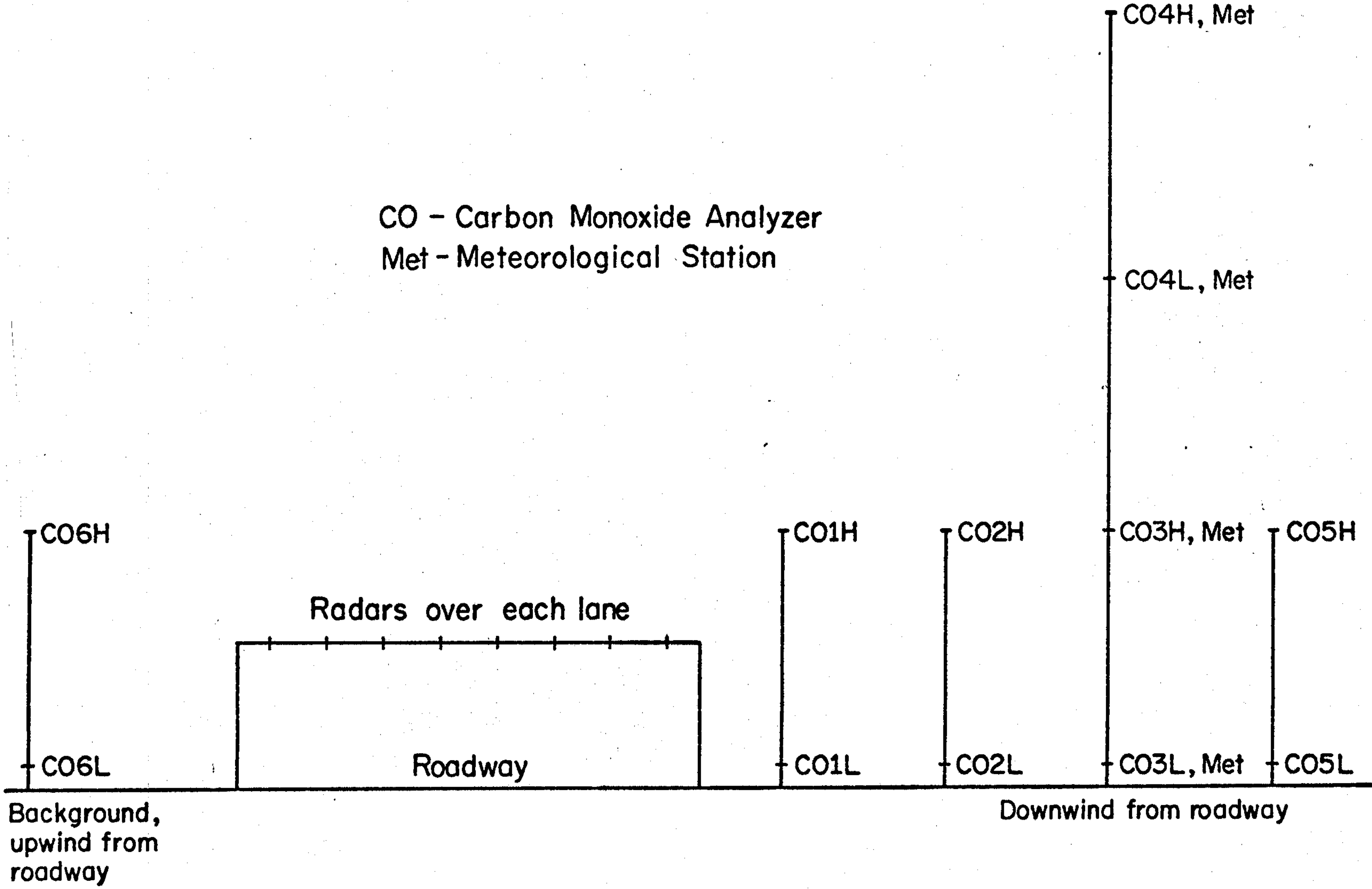

FIGURE 1 Instrumentation Layout for Texas A&M Data Collection Program.

data reduction methods used to render the data useful to researchers. The out-of-state data bases used to develop and compare the improved dispersion model are discussed. An error analysis is listed which compares TRAPS, the Texas Roadway Air Pollution Simulation program developed by project personnel to three other popular dispersion models for 1500 points in five out-of-state data bases.

After publication of Report 218-1, the TRAPS program was optimized by using faster convergence methods for two iterative steps in the program, translating the code into different languages, and increasing the number of error traps. The resulting algorithm was released as two reports, 218-2 and 218-3. Report 218-2 (Bullin and Polasek, 1978a) is a user's guide for TRAPS II, a subroutine version of the TRAPS program designed to run in virtually any ANSI Standard FORTRAN compiler. The routine does no input or output operations, uses only arithmetic IF statements, and calls only ABS, IABS, and ALOG library functions. All inputs and outputs are fully described both in the text and in the source listing provided. Two sample calling routines are provided with output listings. Report 218-3 (Bullin and Polasek, 1978b) provides similar information for a version of the TRAPS program which runs on a Texas Instruments SR 52 hand held calculator. The program occupies three magnetic cards. A source listing and several example problems are contained in the report. Both programs accept inputs in either English units, metric units or a mixture of units. Each report also contains a "Theory of Operation" section, which gives a description of the equations employed, the sources of the equations, and justifications for using them. Each error code is well documented with probable causes and suggestions for error correction.

Report 218-4 (Bullin, et al., 1979) was issued after the data collection phase of the project was complete. The report contains an overall description of the data collection segment of the project as well as a discussion of preliminary findings from the data analysis portion of the project. Detailed site descriptions for all six sites where data was collected are included. Information listed includes topography, equipment layout, data collection periods, and problems encountered. The description of experimental methods is more detailed than that of Report 218-1 and includes information that was not known to the authors when the earlier report was released. Calibration methods, sampling intervals, error recovery procedures, sample conditioning methods, and instrument and system accuracy limits are discussed. In addition, the data reduction procedures followed are fully explained. The report includes source listings of all data reduction programs and sample listings of the data formats available to the user.

Report 218-4 also contains a method developed by project personnel for calculating emission factors from actual dispersion data, independent of emission factor prediction programs such as MOBILE1 (Environmental Protection Agency, 1978). The accuracy of the method was verified by applying it to tracer gas studies in which the emission factor was known. The strong points and weak points of bag sequential samplers are also discussed in the report. Since these samplers were used by virtually all studies previous to Project 218, these devices were evaluated during the data collection phase of this project. Accuracy limits and suggested precautions are included in the report. The final section of Report

218-4 includes the comparison of four models using selected cases from the Texas data base. The cases were selected from those for which an emission factor could be determined from experimental dispersion data by a mass balance method described in the report. The models were run both with emission factors determined from experimental dispersion data and with emission factors determined by MOBILE1. The improvement in accuracy is impressive.

The current report contains a continuation of the data analysis begun in Report 218-4. The TRAPS II model has been further improved by correction of the turbulence parameters and the road edge concentration profile in light of data collected at General Motors (Cadle et al., 1975). The resulting model, the TRAPS II model, and three other well known dispersion models have been compared to the Texas data base for in excess of 2200 data points. Error analyses have been completed for the model results using both MOBILE1 and emission factors determined from experimental data. Various statistical analyses have been used on cases selected at random from the data base. The analyses were chosen to shed light on the structure of the micrometeorological turbulence in the near vicinity of roadways. Since the turbulence process is poorly understood, the results are potentially of great importance to those researchers attempting to work with the effects of this phenomenon.

CHAPTER II

ASSIMILATION OF DATA BASES

In order to develop an empirical diffusion model or test its performance, actual operational data for dispersion of pollutants from roadways are required. The traffic, pollutant levels, roadway geometry and meteorological data should be included in the data base. For the model development and evaluation described in this work, two data bases were used and these are discussed in this chapter.

15-Minute Average Data Base

A subset of the Texas data base in the form of 15-minute averages has been created and used to evaluate five highway air pollution models. The creation of the data base will be described in this section. The next chapter will contain the description of the model development. The chapter following that will consist of the analysis and comparison of the models with the data.

Roadway pollutant dispersion data used for model development or evaluation should, if possible, have known background or ambient pollutant concentration. In addition, it is desirable that the concentration be constant with height. For this reason, the primary criterion for selection of a 15-minute data case, to be included in the data base, was that the background values for carbon monoxide concentration be within 1.0 ppm of each other. In most cases selected, the concentrations of the CO6L and CO6H locations (as shown in Figure 1), which were on the south side of the roadway, represent upwind or background carbon monoxide levels. However, for most cases at the Houston cut site the wind was not out of the south. Therefore, concentration values for locations on the north side of the roadway were considered as background values for those cases. For the Houston cut site, the instrument locations CO4L, CO4H, CO5L and CO5H were outside and upwind of the cut when the wind was from the north. Carbon monoxide concentrations at one or several of these locations were used as background values for northerly wind cases. For cases at the Houston cut site in which the wind was out of the south, the concentrations at the CO6L and/or CO6H locations were used as background values.

For each site, the averaging periods for which essential model input data, such as wind speed, wind direction, insolation, or traffic variables, were either missing or noted as erroneous in the daily log were removed from consideration for selection. The Houston cut site and Dallas elevated site were exceptions. In order to obtain enough cases for the Houston cut site, it was necessary to select cases for which traffic data were missing for one or two lanes. In these cases the traffic count for a given lane was estimated to be the percentage of the total count for that direction of travel. The percentage value was determined from the data for the same time period on another day. The speed for that lane was assumed to be the average speed for all other lanes in that direction of travel.

A more involved routine was necessary to estimate the traffic for the northbound lanes at the Dallas elevated site. No traffic data were collected by radar for those lanes. Loop counter data for those lanes collected by TDHPT, The Texas Department of Highways and Public Transportation, at the time the project was located at this site were used to estimate the traffic. The method of estimation is described in

Appendix A.

For the traffic data available at the Dallas elevated site, one radar was consistently in error in recording traffic speed. Therefore, the average speed was calculated using the remaining good radar values and was used as the speed for both directions of travel.

All of the above estimated traffic variables were edited into the data cases before they were processed. The same cases after editing (if any was done) were also stored. These files include the log messages. The locations of these files are given in Appendix B.

Each of the 15-minute data cases were converted into ten individual records representing each of the ten downwind CO receptors. All meteorological and traffic data were retained in each of the 10 records. Thus each record consists of a value for the single dependent variable, CO concentration, at a particular location and single values for each of the independent variables. The independent variables consist of all of the meteorological and traffic data recorded as well as receptor and roadway geometry variables to be discussed later. The data base in this form may be easily accessed and processed with the computer. The inclusion of only one CO concentration per record with all of the independent variables saves the user the trouble and expense of having to separate each 15-minute data case into single records, which are often necessary for sorting, statistical sampling, and analysis purposes.

The background CO concentration and its standard deviation were also calculated for each 15-minute case. These values were then applied to the downwind CO concentration values and their standard deviations, resulting in values adjusted for background conditions.

For all but the Houston cut site, the background CO concentration was calculated as

$$CO_{background} = (CO6L + CO6H)/2.0 \tag{1}$$

and the standard deviation was calculated as

$$\sigma_{background} = \sqrt{\sigma CO6L^2 + \sigma CO6H^2} \tag{2}$$

The background receptor CO concentration values and their standard deviations were also stored in each record.

For the Houston cut site, the background CO concentration was calculated as the average of those values chosen to represent the background conditions. The standard deviation was calculated as the square root of the sum of the variances for these values. For this site, the calculated value of $\sigma_{background}$ and $CO_{background}$ were stored with each observation instead of the individual background values, as for the other sites.

In addition to recording the data collected, the appropriate roadway geometry and receptor geometry variables were placed in each record at this point in the processing. A standard convention was used for all measurements. The roadway was divided into two sides; side 1 on the leeward side, and side 2 on the windward side. All receptor distances were measured from the downwind edge of the downwind lane of the main roadway on side 1. All roadway separations were measured from nearest lane edge to nearest lane edge. All roadway widths were measured from outside lane edge to outside lane edge. These distances were measured in feet. Roadway angles were assigned on the convention of a system increasing from 0 to 180 degrees traversing from north (0 degrees) to east (90 degrees) to south (180 degrees). For those data not relevant for a particular site a value of zero was entered. The data recorded are described in Appendix C.

The location of the files resulting from the formation of individual records and their format are presented in Appendix D. These files constitute the 15-minute average data base for use in evaluating various dispersion models.

GM Data Base

The GM data base was assimilated from various sources. The main portion of the data base was obtained from the General Motors research report on the sulfate dispersion experiment (Cadle, et al., 1975). Other data were obtained from the literature concerning the experimental results and their application (Chock, 1977). This section describes the building of a data base using all of the above sources.

The data obtained from the research report consisted of vertical wind speed, horizontal wind speed, wind direction, and SF_6 concentration at each sampling location. The temperature at the 3 heights on the towers located 30 m upwind and downwind, total SF_6 flow rates for each day in ℓ/min., and atmospheric pressure in mmHg for each sampling period were also obtained from the report. A variable called acute angle of wind direction with respect to traffic was calculated using the wind direction at the 9.5 m height on the 30 m upwind tower for each sampling period. The sign of the angle is positive for wind flow with traffic on the upwind side of the roadway and negative for flow against traffic on the upwind side.

Using the atmospheric pressure during each sampling period, and the temperature at the 1.5 m height on the 30 m upwind tower, values of SF_6 concentration normalized to a flow rate of 3.5 ℓ/min at 298°K and 760 mmHg were calculated for each receptor location. These were used to obtain a cross road flux value for SF_6 as in the mass balance technique. The values of u_x, the component of wind speed perpendicular to the roadway, were also added to the data base. The values of the flux are recorded in gm/sec $m^2 \times 10^5$, since the SF_6 concentrations were so small.

The above data were assimilated in the data base for only those periods for which the SF_6 flow rate was well controlled and measured. Data for the first two days were not used since there were problems with the tracer release.

Values of u_*, the friction velocity, were calculated using the wind speed at the 1.5 m level at the 30 m upwind tower for each sampling period. The value of u_* is given by

$$u_* = \frac{uk}{\ln(z/z_o)} \tag{3}$$

The roughness height at the sampling site was 3 cm, according to Chock (1977). He also calculated values for stability class using Golder's system and Turner's system for each period. The Turner classifications were entered into the data base since most of the models evaluated in this work use it. The above classification is dependent upon the gradient Richardson number, Ri, and the inverse Monin-Obukhov length, 1/L', both of which were listed by Chock for each period. These variables were entered into the data base. The method of calculation for each is given in the above reference. The definitions of these variables are

$$Ri = \frac{g}{T} \frac{\delta T/\delta z}{(\delta u/\delta z)^2} \quad (4)$$

and

$$1/L' = \frac{g(\delta T/\delta z)}{Tu_*(\delta u/\delta z)} \quad (5)$$

where

T = absolute temperature (K)

u = wind speed at height z (L/t)

z = height at which wind speed is measured (L)

g = gravitational acceleration (L/t^2)

u_* = friction velocity (L/t)

Ri = Richardson number

1/L' = inverse Monin-Obukhov length (1/L)

1/L' was not available for the first two days represented in the data base and is not recorded for those days.

Finally, the sampling periods were divided into groups according to wind speed and direction. This was done using the vector average wind speed of the vertical and horizontal components of the wind speed at the 4.5 m height, 30 m upwind and the wind direction at that location. Wind speed groups consisted of those periods for which $u > 150$ cm/sec and those for which $u < 150$ cm/sec. The angle groups were differentiated at 15° with respect to the roadway. A notation as to whether the wind was from the west side or the east side of the roadway was also made. Each period was converted into 20 individual records, as had been done for the Texas A&M 15-minute data cases. Appendix E gives the name and description of each variable in a record, as well as the location of the data base on tape. This data base consists of 58 averaging periods with 20 records per period.

CHAPTER III

MODEL DEVELOPMENT

Introduction

There are many numerical models that may be used to predict concentrations resulting from the dispersion of material away from a roadway. The three models most frequently used are based on the Gaussian equations for continuous line and point sources. The line source equation is

$$C = \frac{Q' F_1}{\sqrt{2\pi} \, \sigma_z \, u} \left\{ \exp\left[-\frac{1}{2}\left(\frac{z + H}{\sigma_z}\right)^2 \right] + \exp\left[-\frac{1}{2}\left(\frac{z - H}{\sigma_z}\right)^2 \right] \right\} \tag{6}$$

where

Q' = line source strength (m/Lt)

σ_z = vertical dispersion parameter (L)

u = wind speed (L/t)

z = receptor height (L)

H = source height (L)

F_1 = conversion factor

The point source equation is

$$C = \frac{Q F_2}{2\pi\sigma_y\sigma_z u} \left\{ \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2 \right] \right\} \times \left\{ \exp\left[-\frac{1}{2}\left(\frac{z + H}{\sigma_z}\right)^2 \right] + \exp\left[-\frac{1}{2}\left(\frac{z - H}{\sigma_z}\right)^2 \right] \right\} \tag{7}$$

where

Q = point source strength (m/t)

σ_y = horizontal dispersion parameter (L)

y = horizontal receptor distance (L)

The three models based on the above equations differ in the manner in which they are applied. Each of the models is briefly described here. A more detailed description of each is presented in Report 218-1.

CALINE-2

CALINE-2 was developed by Ward, et al. (1977). In this model, the concentration is considered to be uniform in a box over the roadway. This concentration is calculated according to an empirically determined equation. The pollutant concentrations downwind of the box are then calculated using Eq. 6 for perpendicular wind cases and integrating Eq. 7 over the source length for parallel wind cases. The values of σ_y and σ_z are based on work by Turner (1970). For oblique wind cases the downwind concentration is calculated using

$$C_o = C_{per} \sin^2 \theta + C_{par} \cos^2 \theta \tag{8}$$

where

C_{per} = concentration for Eq. 6

C_{par} = concentration for Eq. 7

θ = acute angle of wind wrt/roadway

C_o = concentration for oblique wind

HIWAY

HIWAY was developed by Zimmerman and Thompson (1974). The model uses the point source equation, Eq. 7, which is adjusted according to stability and mixing height. Once the form of Eq. 7 has been determined, it is integrated using a trapezoidal rule.

The dispersion parameters are obtained using Pasquill-Gifford curves, which are presented by Turner. For receptor distances of less than 0.1 km, the curves are extrapolated to a smaller value.

AIRPOL-4

AIRPOL-4 was developed by Carpenter and Clemena (1975), and employs Eq. 7 for point sources. In this model, there is a coordinate system for the roadway and one for the receptors. The roadway coordinate system is mapped onto the receptor system, allowing the equation to be integrated over all roadway points contributing to the pollutant concentration at a particular receptor.

The Pasquill-Gifford dispersion parameters are adjusted to account for the difference in the desired sampling period and the sampling period upon which the Pasquill-Gifford system is based. In addition, an empirical adjustment to the wind speed in the denominator is made. The value of u is not allowed to approach zero, which drives the concentration value to infinity.

The integration of Eq. 7 is simplified in the vicinity of $\theta = 90°$ and $\theta = 0°$. In these regions, separate empirical exponential functions replace Eq. 7.

TRAPS

The TRAPS model was developed as a part of this project. It differs from the previous models in that wind speed and diffusivity are variable with height and site topography affects diffusion. The solution to the general diffusion equation that accounts for the above phenomenon is

$$C = \frac{Q'}{r\ K_1\ x_o} \exp\left(\frac{-\ u_1\ z^r}{r^2\ K_1\ x_o}\right) \tag{9}$$

where

$r = m + 1 > 0$

m = function of wind profile

$x_o = x + x'$

x' = virtual origin distance

u_1 = reference velocity at 1 m

K_1 = eddy diffusivity at 1 m

This solution is for the power law wind speed profile

$$u(z) = u_1\left(\frac{z}{z_1}\right)^m \tag{10}$$

where

z_1 = reference height, 1 m

and the power law eddy diffusivity profile

$$K(z) = K_1\left(\frac{z}{z_1}\right)^\beta \tag{11}$$

for which β was set to a value of 1.0.

The model uses the well known log-law wind speed profile to describe the wind speed.

$$u(z) = \frac{u_*}{k} \ln\left(\frac{z}{z_o}\right) \tag{12}$$

where

u_* = friction velocity

z_o = surface roughness = 0.15 h_c

h_c = average height of surface roughness element

k = von Karman's constant = 0.4

The model finds the best fit m to match Eq. 10 and Eq. 12 over the range of heights (1 m, 16 m). Using this m and c value of K_1 given by

$$K_1 = 0.4\ u_* \tag{13}$$

Eq. 9 is used to find the vertical origin distance. The minimization carried out is

$$G(x') = \sum_{i=1}^{4} (C_i - X_i)^2 \tag{14}$$

where

C_i = concentration given by Eq. 9

X_i = empirically determined concentration at the roadway edge

This minimization is carried out for heights of 5, 10, 15, and 20 feet.

Once all of the parameters have been determined, the concentration of any downwind point may be calculated.

TRAPS II is a revision of the TRAPS model resulting from two major time saving changes. The first change is the determination of m. It was noted that m is a function of z_o only. A fourth order polynomial was fit to 150 values of m for 150 values of z_o. This polynomial replaces an iterative minimization.

The second revision is that the virtual origin distance minimization is performed only for the 5 foot height. This allows direct iteration to be used instead of the secant method in the original TRAPS model. These two changes reduced the computer time by about 50%.

There are many other dispersion models available. Several of them, along with those discussed above, have been evaluated with experimental data. The most important of these evaluation studies were reviewed by Green (1980). These studies have pointed out several areas of weakness in previous models. Some of the weaknesses are: (1) overprediction for low wind speed and parallel wind conditions, (2) inadequacies of the Pasquill-Gifford dispersion parameters, and (3) inaccuracy of EPA MOBILE1 emission factors. These and other problems should be addressed in the development of a new dispersion model.

Development of Modified TRAPS II Model

The first and most important step in the development of the present model was the determination of a description of the pollutant distribution at the edge of the roadway. This distribution constitutes the initial or boundary value condition for the dispersion process. In order to determine the road edge distribution, accurate road edge data were required. The necessary characteristics of such data include accurately determined emission rates and pollutant concentrations and close proximity of sample collectors to the roadway edge. The GM data base fulfills these requirements, since the SF_6 emission rate was well controlled and measured and the SF_6 concentration at various heights within 10 feet of each edge of the roadway were measured accurately down to 10 parts per trillion.

Initial Assumptions:

It has been shown (Green, et al., 1979) that the four most used dispersion models have significant errors for conditions in which the wind speed is low and/or the wind direction is parallel to the roadway. For this and other reasons, the GM data were divided into four groups. These groups were: (1) low wind speed, parallel wind, (2) low wind speed, non-parallel wind, (3) high wind speed, parallel wind, (4) high wind speed, non-parallel wind. The dividing point for the wind speed groups and wind direction groups were as described.

A second assumption was that, at any point, the concentration was directly proportional to the source strength. Under this assumption all road edge concentrations were standardized to a tracer release rate of 3.5 ℓ/min. The conversion is given by

$$SF6STD = \frac{3.5}{V} \times SF6 \qquad (15)$$

where

SF6 = actual SF_6 concentration (ppb)

SF6STD = standardized SF_6 concentration (ppb)

V = actual tracer release rate (ℓ/min)

3.5 = standard tracer release rate (ℓ/min)

Linear Road Edge Model:

Upon examination of the road edge concentration data and the meteorological data, it was noted that the variables with the most influence on the concentration were wind angle, wind speed, and Richardson number. Plots of standardized SF_6 concentration versus each of these variables were made for each height for the road edge receptors. The plots were also made for the component of wind speed normal to the roadway. All of the plots were for receptors on the downwind side of the roadway. These plots revealed that concentration was related more closely to the cross road wind speed, u_x, and Richardson number, Ri, than the other variables.

Using the standardized SF_6 concentration as the dependent variable, and u_x and Ri as independent variables, linear and multiple linear regressions were performed for each height. These regressions were performed for three of the four wind speed-wind angle groups. One of the groups, parallel-low wind speed, had too few observations for analysis. The equations used were

$$\text{SF6STD} = a_0 + a_1 u_x + a_2 \text{Ri} \qquad (16)$$

and

$$\text{SF6STD} = a_0 + a_1 u_x \qquad (17)$$

where the a_i's are regression constants to be determined. The regressions showed that the inclusion of Ri did not significantly improve the regression coefficient, R^2.

For two of the three wind speed-wind direction classes, the height for which the linear u_x equation fit the best was 3.5 m. For the non-parallel-high wind speed cases, one period had to be eliminated to improve the regression coefficient to an acceptable value. For this class, the fit for the 9.5 m level was slightly better than for the 3.5 m level (R^2 = 0.57 vs. 0.53). Since the difference was so small, the equation for the 3.5 m level was used for consistency and simplicity. The constants and regression coefficients for the equation for each group are given in Table 1.

In order to determine the shape of the road edge concentration profile, plots of SF6STD/SF6* versus height are made. SF6* is the value of SF6STD predicted by Eq. 17 for the 3.5 m level. These plots were made for each of the wind speed-wind direction groups. For each of the groups, it appeared that the ratio was approximately linear with height. Therefore, linear regressions were performed, one for each class. The regression equation used was

$$\text{SF6RATIO} = b_0 + b_1 z \tag{18}$$

where

SF6RATIO = SF6STD/SF6*

b's = regression constants

The results of the SF6RATIO regressions are given in Table 2.

The standardized SF_6 concentration prediction according to the predictor equations above may be obtained by

$$\begin{aligned} \text{SF6STD} &= \text{SF6RATIO} \times \text{SF6*} \\ &= (b_0 + b_1 z) \times (a_0 + a_1 u_x) \end{aligned} \tag{19}$$

where the constants are those appropriate for the wind speed and

Table 1. Results of SF_6 Regression for

GM Road Edge Data at 3.5 m Height

Model: $SF6STD = a_0 + a_1 \times u_x$

u_x is at 4.5 m in units of cm/sec.

Group	a_0	a_1	R^2
Parallel, High Wind Speed	2.345 ± 0.136	-0.0304 ± 0.0040	0.83
Non-Parallel, High Wind Speed*	1.229 ± 0.115	-0.0032 ± 0.0008	0.53
Non-Parallel, Low Wind Speed	1.426 ± 0.235	-0.0048 ± 0.0025	0.28

*1 period not used

Table 2. Results of SF6RATIO Regression for

GM Road Edge Data

Model: SF6RATIO = SF6STD/SF6*

$$= b_0 + b_1 \times z$$

z in meters

Group	B_0	B_1	R^2
Parallel, High Wind Speed	1.422 ± 0.052	-0.1113 ± 0.0089	0.81
Non-Parallel, High Wind Speed*	1.700 ± 0.053	-0.1723 ± 0.0090	0.89
Non-Parallel, Low Wind Speed	1.621 ± 0.052	-0.1629 ± 0.0088	0.92

*1 period not used

direction conditions of interest.

In preparing to run for the El Paso road edge, it was noted that the concentrations went negative at very low heights. Therefore, further attempts were made to decrease the scatter in values returned by the road edge concentration predictor equations. In order to determine which variables may affect the total dispersion process, graphical methods were used.

Graphical Methods:

For each of the averaging periods represented in the GM data base, three plots were made: (1) horizontal SF_6 flux profiles (one curve for each height on the same graph), (2) vertical SF_6 flux profiles (one curve for each downwind tower on the same graph), and (3) vertical standardized concentration profiles (one curve for each downwind tower on the same graph). These graphs were made on transparencies using a different color for each curve representing a particular tower or height for a given averaging period.

The transparencies for the horizontal flux profiles were stacked to compare the relationships among the shapes and magnitudes of the profiles for the various heights and the various averaging periods. In this manner, about a dozen groups of averaging periods exhibiting distinct characteristic relationships, among the curves, were formed. Some of these groups contained six or eight averaging periods while other groups contained only one to three averaging periods. For each of these groups, a list of variables, such as wind speed, wind direction, friction velocity, and Richardson number was made.

Upon examination of the variable lists mentioned above, it was noted that there was considerable scatter in the values of the variables within each group and overlap of the ranges of the various variables among the groups. Therefore, no variable or variables distinguishing one group from the others were found.

The vertical flux profile transparencies were divided into the same groups as the horizontal profiles above. Good agreement of curve relationships were exhibited within these groups, as expected. To test the effect of wind angle and wind speed on the vertical flux profiles, the transparencies were divided into the four wind speed-wind direction groups used for the linear road edge model. The curve relationships did not match well within these groups.

Finally, the vertical standardized concentration profiles were divided into groups in the manner described above. As for the flux profile groups, no variables were found to discriminate between wind speed-wind direction groups.

Third Order Road Edge Model:

Upon examination of the vertical standardized concentration profiles for the road edge GM data drawn on the transparencies described previously, it was noted that they were not Gaussian, but appeared exponential with height. Therefore, a polynomial regression approach was taken to describe the road edge concentration profile.

The standardized concentration data for the road edge tower for a single sampling period was used to fit a second order polynomial in height. A plot of the solution showed that the predicted concentration diverges from zero concentration for heights above 9 m. The concentration should approach zero as height increases. In order to force the polynomial to do this, an arbitrary height (20 m) was chosen at which the assigned value of concentration was zero. The second order polynomial was again determined and plotted. For a certain range of heights between 9.5 m and 20 m the predicted concentration values were less than zero. For this reason a third order polynomial was determined to describe the profile. This function allowed concentration to approach zero monotonically as height increases. The function is

$$SF6STD = a_0 + a_1 z + a_2 z^2 + a_3 z^3 \qquad (20)$$

where

a_i's = regression constants

z = height (m)

A set of a_i's was determined for the road edge tower for each of the 58 averaging periods in the GM data base. These coefficients were added to the data base. Correlation coefficients between the polynomial coefficients and the various characteristic meteorological variables were calculated using SAS. The results showed that a_3 and a_2 have a correlation coefficient of -0.99275 and a_2 and a_1 have a correlation coefficient of -0.96724. Therefore, once a_1 is known, a_2 and a_3 may be calculated.

There were no high correlation coefficients for a_1 and a_0. The largest correlation coefficient for a_1 was against a_0 with a value of -0.73. The correlation coefficients for a_0 and the meteorological variables varied from -0.12 (acute angle) to 0.43 (1/L'). A stepwise multiple linear regression routine was used to obtain a best fit of a_0

with the most sensitive meteorological variables. The regression coefficient (R^2) for the fits varied from 0.25 for the best one variable fit to 0.44 for the best seven variable fit. A three variable equation was chosen for a_0 since further addition of variables did not improve R^2 significantly. The equation is

$$a_0 = 2.618 - (0.007577 \pm 0.001797)u_x + (0.009917 \pm 0.004616)\theta + (0.1284 \pm 0.0483)\mathrm{STAB} \quad (21)$$

where

u_x = wind speed normal to the roadway at the 10.5 m height 30 m upwind of the roadway (cm/sec)

θ = acute wind angle with respect to the roadway (degrees)

STAB = Turner stability class (0,1,2,3,4,5, or 6)

This model had a value of 0.43 for R^2.

Chock (1977) has suggested that the process of dispersion of roadway pollutants is sensitive to the direction of the wind with respect to the traffic in the upwind lanes of the roadway. In the development of the model for a_0 the correlation coefficient for SF_6 concentration against a variable called θ_{acute} was checked in order to test this effect. θ_{acute} was the acute angle of the wind with respect to the roadway. Its sign was positive for wind flow with the upwind lane traffic direction and negative for wind flow opposed to the upwind lane traffic direction. The regression coefficient for a_0 against θ_{acute} was the smallest for any of the variables for which coefficients were calculated.

Correlation coefficients between a_0 and the variables were also calculated within each of the wind speed-wind direction classes. The coefficient for θ_{acute} was consistently the smallest. Therefore θ_{acute} was not considered in the predictor equation.

In order to determine if the regression coefficient for the a_0 predictor could be improved, the regression equations of a_0 with various combinations of the meteorological variables as independent variables were determined for each of the wind speed-wind direction groups. In no instance was R^2 improved significantly for any group, and for most combinations of the variables R^2 was decreased, especially for the low wind speed-parallel wind direction group. Therefore, the fit for a_0 used for all conditions was the one listed above.

Since a_1 correlated best with a_0 (R^2 = 0.73), it was cast as a polynomial in a_0. A third order polynomial was chosen as the optimal equation, and it exhibited an R^2 of 0.57. The equation for a_2 was linear in a_1, and the equation for a_3 was linear in a_2. Therefore, given u, θ, and the stability class, the road edge concentration profile may be calculated by

$$a_0 = 2.618 - (0.007577 \pm 0.001797)u_x + (0.009917 \pm 0.004616)\theta + (0.1284 \pm 0.0483)\mathrm{STAB} \quad (21)$$

$$a_1 = (0.9923 \pm 0.6463) - (1.303 \pm 0.612)a_0 + (0.3788 \pm 0.1862)a_0^2 - (0.03946 \pm 0.01696)a_0^3 \quad (22)$$

$$a_2 = (-0.02118 \pm 0.00234) - (0.1136 \pm 0.0041)a_1 \quad (23)$$

$$a_3 = (2.7169 \times 10^{-4} \pm 2.308 \times 10^{-5}) - (0.031604 \pm 0.000508)a_2 \quad (24)$$

$$SF6STD = a_0 + a_1 z + a_2 z^2 + a_3 z^3 \quad (20)$$

$$SF6 = V/3.5 \times SF6STD \quad (25)$$

where u_x, θ, STAB, and SF6STD are as described previously, and SF6 is the concentration in ppb for a pollutant flowrate of V in ℓ/min.

In order to check how well the road edge predictor fit the data, a regression for the predicted and data values for the road edge receptors was performed. The regression equation was

$$P = a_0 + a_1 O \quad (26)$$

where

O = observed concentrations

P = predicted concentration

a_0, a_1 = regression constants

For the 172 points used in the regression the values of a_0 and a_1 were determined to be 0.165 ± 0.043 and 0.873 ± 0.026, respectively. Perfect fit values for a_0 and a_1 are 0.0 and 1.0, respectively. The coefficient of determination, R^2, for this fit was 0.87. These statistics were considered to reflect satisfactory performance of the road edge predictor. Since the predictor equation for SF_6 is not bounded at $SF_6 = 0$, negative values may be obtained. This is most likely to occur for heights greater than 10 m, and was not observed to occur for lower heights on any occasion. Therefore, in the final model, when a negative concentration value is predicted it is automatically reset to 10^{-20}.

The road edge SF_6 concentration model may be transformed to a model for CO, as shown in Appendix F. After this conversion, the model is

$$CO = 4.084 \times 10^{-4} \times \frac{SF6STD \times EF \times VOL}{W} \qquad (27)$$

where

CO = carbon monoxide concentration (ppm)

SF6STD = SF_6 concentration predicted by Eq. 17

EF = carbon monoxide emission factor (gm/veh mi)

VOL = traffic volume on roadway (veh/hr)

W = roadway width (m)

Dispersion Away From Roadway:

The road edge model discussed previously is a boundary condition for the time averaged process of dispersion of a pollutant away from a roadway. The next step in developing a model was to predict the dispersion of material downwind of the roadway, starting with the boundary condition profile.

In the course of determining how to model the dispersion, the properties of four of the currently available diffusion models were examined. These four models were AIRPOL-4A, CALINE-2, HIWAY, and TRAPS II. The examination of these models consisted of checking how well they simulate the transport process involved in dispersion of material away from a roadway.

The transport process may be characterized by using the mass balance concept developed by Bullin et al. (1979). In this method, the mass flux profile at a vertical line downwind of the roadway is constructed. The value of flux for each height is calculated by

$$CO_m = CO \times u_x \times 1.14 \times 10^{-3} \ \frac{\text{gm CO}}{\text{m}^2 \ \text{ppm}} \ \times 1609 \ \frac{\text{m}}{\text{mi}} \qquad (28)$$

where

CO_m = mass flux of CO perpendicular to the roadway (gm CO/m^2 hr)

and CO and u_x are expressed in ppm and miles per hour, respectively. All of the variables in Eq. 28 should be measured at the particular heights for each value of CO_m.

The development of this equation is presented by Bullin, et al., (1979). It may be noted that if CO_m is plotted as a function of height, the area bounded by the curve and the lines z=0 and CO_m=0 will represent the mass of CO emitted from the roadway per unit length of roadway per unit time assuming background CO concentration is zero.

A model for prediction of CO concentrations resulting from roadway pollution should account for the transport of CO away from the roadway, since the concentrations are determined by the transport process. Since the mass flux profile characterizes the transport process, it may be used as a check to tell how well a given model accounts for the transport process.

Two representative cases from the mass balance work were used to check the four models on two points. These points were: (1) Does the mass flux profile produced by each of the models represent the mass flux profile calculated from the data, and (2) Does each of the models exhibit the property of conservation of mass?

The above check was performed by calculating CO_m at various heights for each of the models using the predicted CO concentration values, the input wind speed and direction, and the input emission factor and traffic volume. The resulting mass flux profiles were compared to the profile resulting from the data for each case. Each of the model curves were also integrated and the resulting emission factor was calculated and compared to the input emission factor. The resulting emission factor was calculated by

$$EF_c = A_{mf} \times L \times M \times \frac{1}{VOL} \times 1609 \frac{m}{mi} \tag{29}$$

where

A_{mf} = area bounded by the mass flux curve and the lines z=0 and CO_m=0 (in^2)

L = height scale (m/in)

M = mass flux scale (gm CO/m^2 hr in)

EF_c = the calculated emission factor (gm/veh mi)

VOL = traffic volume (veh/hr)

The data and model curves for the two cases are presented in Figures 2 and 3. The input information is given in Tables 3 and 4.

All models, except TRAPS II, take into account the wind angle with respect to the roadway. Also, all models, except TRAPS II, use a wind speed that does not vary with height. Therefore, in the calculation of CO_m for TRAPS II, the wind speed at each height is used in place of u_x. The values of u were calculated using the log law wind profile and the friction velocity, u_*, and roughness height for the particular model runs.

The data curve in Figure 2 has a shape that is representative of almost all curves for the mass balance data cases. The data curve in Figure 3 is a variation of the general data curve shape. It is obvious

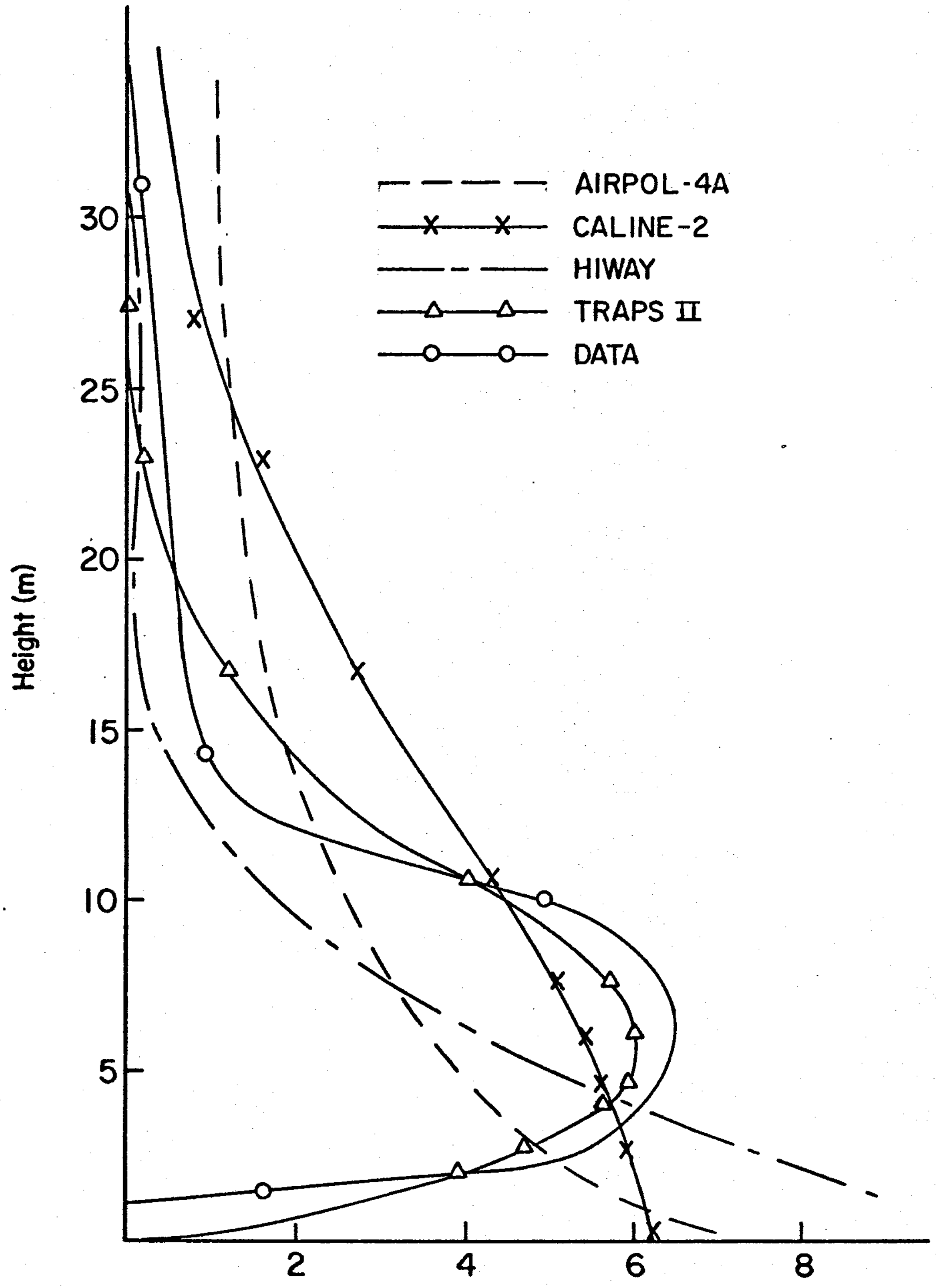

FIGURE 2 Comparison of Mass Balance Curves for Model Results and Data January 12, 1977 6:50-6:55 p.m.

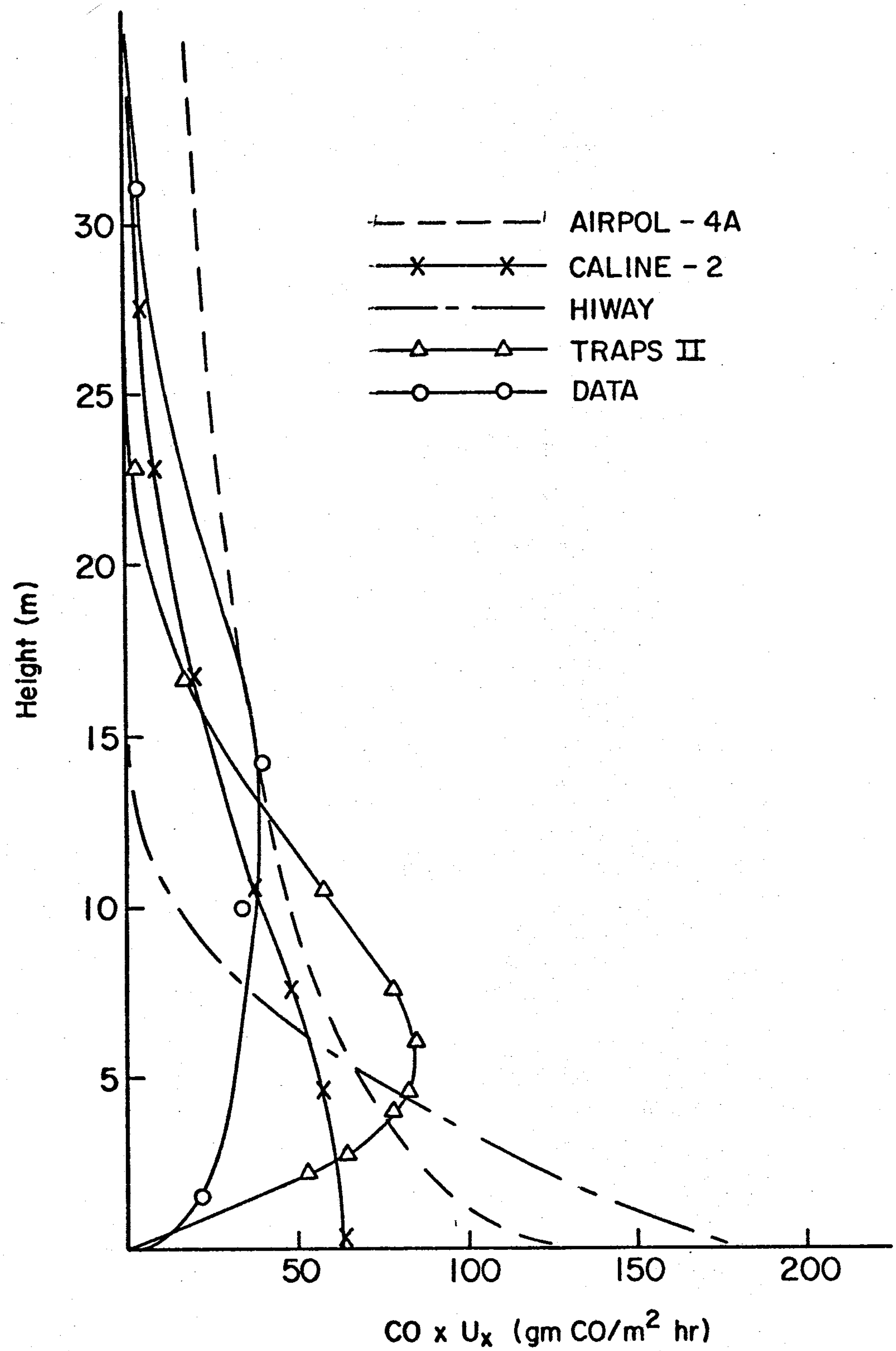

FIGURE 3 Comparison of Mass Balance Curves for Model Results and Data May 26, 1976 2:25-2:30 p.m.

Table 3. Model Input Information for Mass Balance Case May 26, 1976
2:25-2:30 pm

MODEL	WIND SPEED (mi/hr)	WIND DIRECTION (o)	EMISSION FACTOR (gm/veh mi)	TRAFFIC VOLUME (veh/hr)	NUMBER OF SIGNIFICANT FIGURES IN CO CONCENTRATION
AIRPOL-4A	11.9	73	222	6000	3
CALINE-2	12.0	73	222	6000	2
HIWAY	10.3	73	222	6000	3
TRAPS II	12.0	NA	222	6000	2

Table 4. Model Input Information for Mass Balance Case January 12, 1977
6:50-6:55 pm

MODEL	WIND SPEED (mi/hr)	WIND DIRECTION (o)	EMISSION FACTOR (gm/veh mi)	TRAFFIC VOLUME (veh/hr)	NUMBER OF SIGNIFICANT FIGURES IN CO CONCENTRATION
AIRPOL-4A	7.4	12	15.5	6240	3
CALINE-2	7.0	12	15.5	6240	2
HIWAY	6.0	12	15.5	6240	3
TRAPS II	7.0	NA	15.5	6240	2

upon comparison of the curve shapes, that TRAPS II is the only model that represents the actual transport characteristics exhibited in the data curves. This is true since it is the only model for which CO_m approaches zero as height approaches zero and has a maximum CO_m value at $z > 0$.

The results of the mass conservation check are presented in Tables 5 and 6. It may be seen in these results that for the parallel wind case (January 12), CALINE-2 is out of mass balance by 80 percent while AIRPOL-4A is out of mass balance by at least 28 percent in one case and 80 percent in the other. These are minimum values, since there is substantial area under the mass flux curve for AIRPOL-4A above 30 m in both cases. HIWAY exhibits good mass conservation properties for both cases, and TRAPS II is within 20 percent of mass conservation for both cases. Twenty percent should be considered respectable agreement, considering the number of significant digits for CO concentration returned by TRAPS II and the error involved in the data as well as the mechanical integration of the area.

Since TRAPS II and HIWAY were the only models that were consistent with respect to mass conservation, and since only TRAPS II reflects the mass transport characteristics exhibited by actual data, TRAPS II clearly represents the process of pollutant dispersion the best. The above comparison indicates that TRAPS II avoids problems of overprediction for parallel winds, which are encountered with other models, as discussed previously.

TRAPS II uses the only available analytical, non-Fickian solution to the general diffusion equation. This solution incorporates a variable wind speed with height and exhibits the transport characteristics discussed above. Therefore, it was decided that the road edge predictor

Table 5. Results of Mass Conservation Check for Models for Case May 26, 1976, 2:25-2:30 pm

MODEL	AREA UNDER MASS FLUX CURVE (m^2)	SCALE ($\frac{gm\ CO}{m\ hr\ m^2}$)	CALCULATED EMISSION FACTOR (gm/veh mi)	% ERROR
AIRPOL-4A	5.61+	250	376+	+70+
CALINE-2	3.48	250	233	+5
HIWAY	5.20	250	348	+2
TRAPS II	3.93	250	263	+18

Table 6. Results of Mass Conservation Check for Models for Case January 12, 1977, 6:50-6:55 pm

MODEL	AREA UNDER MASS FLUX CURVE (m^2)	SCALE ($\frac{gm\ CO}{m\ hr\ m^2}$)	CALCULATED EMISSION FACTOR (gm/veh mi)	% ERROR
AIRPOL-4A	7.73+	10	19.9+	+28+
CALINE-2	10.8	10	27.9	+80
HIWAY	6.13	10	15.8	+2
TRAPS II	7.01	10	18.1	+17

model should be used in a modification of TRAPS II.

Modification of TRAPS II:

The modification of TRAPS II consisted of three main points: (1) improving the function used to find the virtual origin distance, (2) decreasing the lower bound for roughness height from 0.4 to 0^+ feet, and (3) adjusting the empirical eddy diffusivity.

To find the virtual origin in the original TRAPS model, Maldonado (1976) performed a minimization with respect to x' for the function.

$$G(x') = \sum_{i=1}^{4} (C_i - X_i) \tag{14}$$

where

C_i = concentration predicted by Eq. 9

X_i = empirically calculated downwind road edge concentration

x' = virtual origin distance

This minimization was performed for four heights (5, 10, 15, and 20 feet) at the roadway edge. The values of X_i were given by

$$X = X_* \exp(a_0 + a_1 z) \tag{30}$$

where

X_* = concentration at the 5 foot height at the roadway edge

z_i = height

a_i's = empirically determined constants

X_* is calculated by

$$X_* = \frac{a\ Q'}{u_{10}\ W} \quad (31)$$

where

Q' = line source strength (M/Lt)

u_{10} = wind speed at 10 m (L/t)

W = roadway width (L)

a = empirically determined constant

The coefficients of determination for Eqs. 30 and 31 were 0.17 and 0.85, respectively. The former coefficient indicates that the road edge concentration model performed poorly when applied to the entire profile. This was due primarily to the lack of good data at the time.

The TRAPS II model uses only the 5 foot concentration at the roadway edge to find the virtual origin distance. In the present work, this routine was removed from TRAPS II and replaced with a routine incorporating the new road edge model given by Eq. 27. This minimization is performed for heights of 2, 11, and 31 feet.

Since the minimization function has an odd number of roots on the open interval $(0 < x' < \infty)$, the numerical routine locates the root corresponding to the global minimum. The interval (0^+ feet, 500 feet) is searched for this root.

It should be noted that, in Eq. 31, wind speed is in the denominator. Thus, as wind speed approaches zero, the 5 foot height road edge concentration approaches infinity. Therefore, the lower limit allowed by TRAPS II for wind speed is 0.54 m/sec (1.2 mi/hr), because this was the lowest wind speed used in developing the equation. Since Eq. 9 was developed for all wind speeds $(0 \leq u < \infty)$ and wind speed does not appear in any denominator in the new road edge predictor, Eq. 27, the exclusion of low wind speed cases is theoretically eliminated. The lowest wind speed contained in the experimental data used to develop the road edge model was about 0.8 miles per hour.

The second modification involved decreasing the lower bound for the roughness height. TRAPS II does not allow a roughness height of less than 0.4 feet to be used. Since the roughness height for the GM data was 0.1 feet, the present model was developed to include all roughness heights.

In the TRAPS II model, the roughness height is used to determine the parameter, r, in Eq. 9. This parameter is calculated by

$$r = m + 1 \tag{32}$$

In Eq. 32, m is the "best fit" m for matching the log-law and power-law wind speed profiles. These profiles are calculated, respectively, by Eqs. 12 and 10. Bullin and Polasek (1976) noted that m is a function only of roughness height, z_0. They determined a fourth order polynomial to return a value of m for roughness heights of 0.1 to 1.0 meters. In the same manner, for this work, a fourth order polynomial was determined after finding ten values of m for the interval 0.01 to 1.0 meters. This polynomial is

$$m = 0.12258 + 4.0935 \times z_0 - 59.468 \times z_0^2 + 550.01 \times z_0^3 - 1965.5 \times z_0^4 \tag{33}$$

where z_0 is expressed in meters.

The present model was run for the GM cases after the above modifications were made, and the results were compared with the data. This comparison revealed that the predicted concentrations at the far downwind tower were too large for the bottom receptor and too small for the top receptor. This indicated that the material was modeled as dispersing upward less rapidly than actually occurred in the GM data.

The implication with respect to the model was that the eddy diffusivity, K_1, used in Eq. 9 is too small. This eddy diffusivity is given by the empirical relationship in Eq. 13. This equation is for neutral conditions in the ambient atmosphere, and does not take into account the turbulence generated by traffic on a roadway. In an attempt to account for the traffic turbulence, the model was run for the GM cases using a value of 0.6 for the constant in Eq. 13. This reduced the predicted concentrations at the lower levels and increased them at the upper levels, but the change was not enough to match the data values.

The model was run again for the GM cases using a value of 0.8 for the constant in Eq. 13. This produced satisfactory results with respect to the upward dispersion of material when compared to the GM concentration data. Thus, in the present work, the value of the constant in Eq. 13 was set to 0.8.

The model encompassing the three modifications above is called TRAPS IIM, which stands for TRAPS II, modified. A source listing of the model is given in Appendix G. Further modifications taking into account depressed, elevated, and viaduct roadways, and bouyancy effects for low wind speed cases should result in a TRAPS III model.

TRAPS IIM has been evaluated along with AIRPOL-4A, CALINE-2, HIWAY, and TRAPS II. This evaluation is presented in the next chapter.

CHAPTER IV

PROJECT RESULTS

Introduction

The results from the project work since Report 218-4 are discussed in this chapter. Extensive work was performed in the area of statistical analysis of the instantaneous data values. One of the exceptional features setting the Texas data base apart from most other data bases is the instantaneous data values, not only for the meteorological instruments, but also for the pollution monitors as well. A battery of statistical tests were run for several cases at several sites.

The model evaluation work is also extended in this chapter. The prominent dispersion models were run for many cases from the Texas data base as well as a number of cases extracted from the General Motors data base. Several statistical parameters are listed which give the user a better indication of model accuracy than visual examination of the raw predictions. Also included are the computer time and core requirements of the various models, which give an indication of the expense of running these models.

Statistical Analysis of Experimental Data

The Texas data contains instantaneous measurements which were made at frequent intervals. This type of pollutant dispersion information has not been available in the past. For this reason, a highly detailed statistical analysis on several data sets was made. Moe, et al. (1978) has already examined two cases in considerable detail and noted a number of interesting effects not predicted by theory and not visible in the averaged data.

Eight 25 minute periods were selected from the data base for statistical analysis. Two cases were selected from each of the last four sites. Because traffic, temperature, relative humidity, and radiation were recorded only once per minute, these instruments did not have enough values during a 25 minute period for a useful statistical study and these instruments were not included in the analyses. The instruments subjected to statistical analysis were the horizontal anemometers, wind vanes, carbon monoxide monitors and, if present, the NO_x monitors. The data from the wind vanes were modified by taking the sine of the wind angle with respect to the roadway, and the pollutant data were corrected for zero and span errors.

The fifteen minute averages were examined to select the cases to be analyzed. Six criteria were used to choose the cases. These criteria were:

1) At least eight Ecolyzers had to be operating downwind of the roadway for two consecutive averages.
2) The Ecolyzers had to be showing significant pollution levels.
3) The average wind speed had to be at least three miles per hour and the direction had to be at least 30 degrees with respect to the roadway.
4) One case was selected shortly after arriving at each site and the other case selected shortly before leaving the site.
5) One case was selected to correspond to a mass balance case listed in Report 218-4.

6) At all sites except El Paso, one case was selected in the morning and the other in the afternoon. At the El Paso site, morning winds were either light or northerly, making these cases poor for statistical analyses.

The selected cases were:

Dallas Elevated	May 19, 1977	17:00 - 17:25
	June 9, 1977	08:00 - 08:25
Dallas at Grade	July 20, 1977	16:10 - 16:35
	August 11, 1977	07:20 - 07:45
San Antonio	October 6, 1977	08:00 - 08:25
	October 17, 1977	17:00 - 17:25
El Paso	November 29, 1977	12:50 - 13:15
	December 2, 1977	15:00 - 15:25

The downwind Ecolyzer data were plotted against time for all these cases. Figures 4 through 9 are the results of this effort for the August 11 and October 17 cases. Each figure contains a series of four graphs representing a concentration profile; either from ground level to 100 feet or horizontally away from the roadway at a fixed height. Some general conclusions can be drawn from these figures alone. First, "puffs" of carbon monoxide can be seen traveling through the system quite rapidly. In fact, some of these puffs seem to reach the further downwind and higher altitude monitors before they reach the monitors nearer the road. This leads the authors to believe that most of the time delays observed are due to instrument lag rather than real delay. Second, the largest of these puffs reach 100 ft in altitude at only short distances from the roadway, causing noticeable effects at this altitude within 150 ft of the downwind road edge. This means that vertical dispersion was faster than predicted by most air pollution dispersion models, which predict essentially no dispersion at that height and distance. Third, as could be expected, horizontal or vertical distance softens the sharpness of the fluctuations as well as lowering the average concentration.

After these graphs had been thoroughly examined, the August 11 and October 17 cases were analyzed by a number of statistical methods. Analysis methods included power spectra, autocorrelation and cross correlation with lag, and probability densities. In some respects, the results of these tests confirmed the intuitive feelings gained from studying Figures 4 through 9, but in other respects, the results were decidedly unexpected. Examination of the figures would lead one to believe that large amounts of power are contained in the frequency range of one to two cycles per minute, particularly for an instrument such as CO3L at the October 17 site, shown in Figure 8. This expectation was incorrect.

The most surprising result of the analysis was that virtually all of the signal power was confined to frequencies of less than one half cycle per minute for all the instruments. Figures 10 and 11 show the spectra of two of the instruments with the highest frequency power. As can be seen, the power involved in frequencies of greater than 0.5 cycle per minute is negligible. Thus, according to the power spectra, data collection could have been carried out at lower rates with no loss of statistical accuracy. Figures 4 through 9 do not seem to bear this out. The abrupt changes in direction at each data point would tend to indicate that to be representative, the data should be collected more rapidly, not less rapidly. Thus the power contained in the higher frequencies is negligible compared to the power in the low frequencies.

The autocorrelation confirmed the power spectra results. The autocorrelation coefficients remained high at all lags, indicating that most of the signal power was contained in cycles of at least 20 minutes or longer. With suitable scale expansion, the structure of the autocorrelation function could be seen to provide evidence of some shorter term cycles imposed on the main one. In particular, the horizontal anemometers showed a cyclical behavior at between 3.5 and 4 minutes per cycle at both sites, the wind vanes showed a small peak at 1 to 2 minutes per cycle and a larger one at 5.5 to 6 minutes per cycle. The Ecolyzer data was much noisier, but numerous instruments showed a 2.75 minute cycle and a 5.5 minute cycle. All these cycle times are extremely slow, making them hard to see in the power spectra. Figures 12 and 13 show samples of these instruments' autocorrelation functions.

The cross correlation with lag produced little in the way of useful results. The lags associated with the highest correlation coefficients showed little correspondence with each other except for carbon monoxide instruments located close to one another. The Ecolyzers in each single tower tended to give a consistent lag picture, but overall, the lags seemed to be essentially random numbers. Correlation coefficients, however, were very high. This paradoxial result can be easily explained if one looks back at the autocorrelation functions. Apparently the fluctuations are so small with respect to the base signal that the cross correlation can only "see" the steady component and gives good correlation coefficients no matter what the fluctuations look like.

Potentially the most important finding of the statistical analysis was the existence of non-Gaussian wind speed and carbon monoxide concentration distributions. Figure 14 shows an example density graph. The solid lines show the actual densities of the various values, and the dotted line shows the probable shape of the density curve if the number of points were increased enough to smooth the curve. The shape is clearly not the standard "bell" of a Gaussian distribution. The shape is skewed in a rightward direction. Consideration of the process involved tends to support the contention that the curve cannot be Gaussian in shape. The Gaussian probability distribution runs from minus infinity to plus infinity and is symmetric about the mean. That is, a value is just as likely to be three standard deviations below the mean as it is to be three standard deviations above the mean. But if the mean carbon monoxide level is 2.0 ppm with a standard deviation of 1.0 ppm, the probability of a point lying three standard deviations below the mean is zero, since negative concentrations do not exist. However, the possibility very definitely exists for a point to be three standard deviations above the mean. A similar argument holds for the wind speeds. Thus, the assumption which many models use, that wind speed and carbon monoxide concentrations are normally distributed, may not be correct. The probability density of the wind vane data showed essentially what was expected, at least for the cross wind cases examined. Figure 15 shows an example. Since the sine of the wind direction is bounded by one at 90° and symmetric about one, the distribution looks like half a Gaussian curve. If oblique wind cases had been chosen, this profile could also have been distorted with unpredictable results on model assumptions.

Comparison of Model Predictions to Experimental Data

Five roadway pollution dispersion models, AIRPOL-4A, CALINE-2, HIWAY, TRAPS II, and TRAPS IIM, were run for each of the sampling periods in the Texas 15-minute average data base described previously, the GM data base, and the Texas mass balance data base. The predicted values of CO concentration were used to calculate statistics to be used for comparison and evaluation of the models. The type of statistics used in the present work is the same as that used by Bullin and Maldonado (1977) in a previous evaluation of the first four models above. As discussed by Maldonado (1976), the most important evaluation statistic is average squared error of prediction, which is a maximum likelihood estimate for σ^2. This is the variance of the model prediction error under the assumption of normal distribution and constant variance. This statistic may then be used to find the probable error or 50% confidence limit of the error. For the present study, the regression for Eq. 17 was performed for each model for each site in the Texas data base, for each model for the total Texas data base, and also for the GM data and the mass balance cases.

Model Input Information:

Each model has a particular set of input variables and conventions for determining these variables. The conventions peculiar to each model are not discussed here because of their length, but may be obtained from the respective user's guides (Zimmerman and Thompson, 1975; Jones and Wilbur, 1976; Carpenter and Clemena, 1976; Bullin and Polasek, 1978a). The method of selecting input variables for the data cases coincided as nearly as possible to those described in the user's guides. Those departures from the user's guide methods that are worthy of note are discussed.

Emission Factors. The values of the input emission factors were obtained using the EPA MOBILE 1 program for the Texas data. The input variables for the program pertaining to vehicle type mix, operating mode mix, and the vehicle age distribution were obtained as county-wide values from TDHPT. The values used as inputs to MOBILE 1 are: 1) By-lane speeds and counts from project radars. 2) For MOBILE 1, the vehicle type mix and percent cold start and hot start as presented in Tables 6a and 6b, were used. 3) For any parameter not specified, the national average was used. The vehicle age distribution used for all sites was that for Harris County for 1976. This should represent the vehicle age distribution in Texas better than the national average values. The temperature and traffic speed to the nearest 5° F and 5 mph were obtained from MOBILE 1.

The values for the emission factor returned by MOBILE 1 constitute the greater source of error in dispersion model imput data. This is because traffic conditions (vehicle type, mode, and age mix) may vary widely throughout the day and may be considerably different for freeway conditions than for the county overall.

The form of the emission factor required for all models, except HIWAY, is a single value expressed in units of gm CO/veh mi, which are the units returned by MOBILE 1. For the HIWAY model, an emission rate value for each lane of traffic is required and is expressed in units of gm CO/sec m. The MOBILE 1 emission factor may be converted to the emission rate as illustrated in Appendix H.

The emission rates for the GM sampling periods were known and these were used to calculate emission factors. Even though the emission rates were known, the calculation of the emission factors required considerable effort. The

Table 6a

1976 Harris County Vehicle Age Distribution

by Vehicle Type - (Source DMV)

Year	Automobile,%	Pickup,%	Heavy Duty Gas,%	Heavy Duty Diesel,%
1976	8.7	10.4	6.1	6.1
1975	10.5	11.4	12.8	13.6
1974	12.3	12.7	13.7	16.7
1973	12.7	12.1	13.7	17.1
1972	10.5	9.2	10.9	9.7
1971	8.3	6.8	7.6	8.2
1970	7.7	6.2	7.0	8.0
1969	7.0	6.4	6.8	6.8
1968	5.9	5.1	5.0	4.3
1967	4.4	4.1	3.9	2.8
1966	3.7	3.9	3.2	2.3
1965	2.9	3.2	2.4	1.6
pre - 1965	5.5	8.5	7.0	2.9

Table 6b

Vehicle Operating Mode for MOBILE-1

City	County	PCCO[a]	PCHS[b]	PCCC[c]
Houston	Harris	15.1	27.1	24.4
Dallas	Dallas	19.2	34.5	27.8
San Antonio	Bexar	23.3	31.8	31.2
El Paso	El Paso	17.9	30.1	25.4

a - % of non-Catalyst-equipped light duty vehicles vehicle miles traveled accumulated in cold start mode
b - % of catalyst-equipped light duty vehicles vehicle miles traveled accumulated in hot transient mode
c - % of catalyst-equipped light duty vehicle vehicle miles traveled in cold start mode

Vehicle Type Mix for MOBILE-1

City	County	LDV[a]	LDT1[b]	LDT2[c]	HDG[d]	HDD[e]	MC[f]
Houston	Harris	0.725	0.171	0.042	0.023	0.006	0.033
Dallas	Dallas	0.720	0.176	0.043	0.023	0.006	0.031
San Antonio	Bexar	0.720	0.176	0.043	0.023	0.006	0.031
El Paso	El Paso	0.720	0.176	0.043	0.023	0.006	0.031

a - Light Duty Vehicles (automobiles)
b - Light Duty Trucks (lower weight class)
c - Light Duty Trucks (upper weight class)
d - Heavy Duty Gas Vehicles
e - Heavy Duty Deisel Vehicles
f - Motor Cycles

calculation procedure is presented in Appendix I.

Stability Class. All of the models except TRAPS II require a value of stability class. In order to calculate this variable, the wind speed at the second level from the ground and the insolation were used. Knowing these variables the Pasquill or Turner stability class may be determined. The Turner stability class for the GM sampling periods were obtained from the literature, as noted previously.

Roughness Height. TRAPS II and TRAPS IIM require a value for roughness height, which is defined as 0.15 times the height of the average roughness element for the given site. TRAPS II will return an error code for conditions of low wind speed, small roughness height, and narrow road width. Therefore, the values used for roadway width and roughness height were the minimum for which the model program would execute successfully if the true values were too small. The roughness height used for each site is given in Table 7. The same heights were used for TRAPS IIM, except that 0.1 feet was used for the GM site.

Mixing Layer Height. A value of 5000 m was used as a mixing layer height for the HIWAY model, since concentrations were calculated for only the lower 100 ft of the atmosphere close to the roadway.

Source Length. The upwind and downwind source lengths are required for the HIWAY and AIRPOL-4A models. For sites at which the roadway extended very far in a straight line in either direction, a value of one mile was used. If the roadway curved greatly or intersected another major thoroughfare at less than one mile distance, the distance to the curve or roadway was used. For the GM case a length of 2.5 km was used for each direction, since the site was in the middle of a 5 km track. The values used for each site are given in Table 8.

Table 7. Rougness Height Used for TRAPS II

Site	TRAPS II Roughness Height (ft)
Houston at-grade	2.5
Houston cut	NA
Dallas at-grade	1.0
Dallas elevated	NA
San Antonio	2.5
El Paso	2.62
GM	0.4

Table 8. Source Lengths for HIWAY and AIRPOL-4A Models

Site	Source Length (ft)
Houston at-grade	5,280
Houston cut	5,280
Dallas at-grade	5,280
Dallas elevated	5,280
San Antonio	1,320
El Paso	2,640
GM	8,200

Site Geometries. The roadway geometry for each site used for each model was as follows:

CALINE-2 - Houston at-grade - The model was run one time for the entire main roadway.

CALINE-2 - Dallas at-grade - The model was run once for each of the access roads and for each direction of travel on the main roadway for each case.

CALINE-2 - San Antonio - The model was run once for the westbound access road and the main roadway for each case.

CALINE-2 - El Paso - The model was run one time for the entire roadway for each case. For this model, as well as for the others, two different definitions of the downwind roadway edge were used for two different groups of averaging periods because of the location and complexity of the site. For wind directions with respect to the roadway between 0° and 135° measured from the eastern extension, the road edge was considered to be the edge of the outside lane for the westbound side. For angles of 136° to 180° the characteristic roadway would be the western extension. The outside lane ends at a short distance to the west of the site. Since local drivers would realize this and therefore avoid that lane, that lane was not included in the effective roadway. Therefore, the edge of the roadway was defined as the edge of the second lane from the outside of the actual roadway.

CALINE-2 - Houston cut - The model was run once for the entire roadway.

CALINE-2 - GM - The model was run once for each direction of travel.

For this model, as well as for the others, the effective roadway was defined as the outside two lanes in each direction of travel, since they were the only ones carrying traffic.

CALINE-2 - Dallas elevated - The model was run once for the entire roadway.

TRAPS II - Houston at-grade - This combination was handled the same as for CALINE-2.

TRAPS II - Dallas at-grade - This combination was handled the same as for CALINE-2, except that TRAPS II has a lower limit of 29 feet for roadway width. Since the individual roadway widths at this site were less than 29 feet, extra width was added on the upwind side to satisfy the requirement.

TRAPS II - San Antonio - This was handled the same as for CALINE-2, except that the width fixup, as above, was used for the access road.

TRAPS II - El Paso - This combination was handled the same as for CALINE-2.

TRAPS II - Houston cut - TRAPS II does not apply to below grade roadways.

TRAPS II - GM - This combination was handled the same as for CALINE-2, except that a roadway width of 35 feet was the minimum for which the model would execute successfully. This in nine feet wider than the effective roadway.

TRAPS II - Dallas elevated - TRAPS II does not apply to elevated roadways.

AIRPOL-4A - Houston at-grade - Each direction of travel on the main roadway was handled as a distinct lane group for each case.

AIRPOL-4A - Dallas at-grade - Each access road and each direction of travel on the main roadway was handled as a distinct lane group for each case

AIRPOL-4A - San Antonio - The westbound access road and each direction of travel on the main roadway was handled as a distinct lane group for each case.

AIRPOL-4A - El Paso - Each direction of travel on the main roadway was treated as a distinct lane group for each case.

AIRPOL-4A - Houston cut - Each direction of travel on the main roadway was treated as a distinct lane group for each case.

AIRPOL-4A - GM - Each direction of travel was treated as a distinct lane group for each case.

AIRPOL-4A - Dallas elevated - Each direction of travel was treated as a distinct lane group for each case.

HIWAY - Houston at-grade - The model was run once for the entire main roadway for each case.

HIWAY - Dallas at-grade - The model was run once for each access road and once for the main roadway for each case.

HIWAY - San Antonio - The model was run once for the westbound access road and once for the main roadway for each case.

HIWAY - El Paso - The model was run once for the entire roadway for each case.

HIWAY - Houston cut - The model was run once for the entire roadway for each case.

HIWAY - GM - The model was run once for the entire roadway for each case. HIWAY Version 74015 was used for all sites, including this one. This version would not execute for stability class 6.

Therefore, HIWAY Version 75128 was used for these cases.

HIWAY - Dallas elevated - HIWAY does not apply to elevated sites.

TRAPS IIM - The model was run once for each case for all of the sites, except the elevated and cut sites to which the model does not apply.

Location of Model Input Data Sets and Model Results:

The model input data sets and the model results are stored on tape. The model results were also added to the individual data records discussed in Chapter II. The locations, identifications, and formats of the model input and model results are given in Appendix J. The output formats are listed in Appendix J. The data records along with the model predictions are also described in Appendix J.

Results of Comparisons:

The results of the statistical comparison of the model predictions with the data are presented in this section. The results consist of the number of points for which predictions were made, average error (measured concentration minus model prediction), probable error, average squared error, maximum error, and minimum error. The regression constants for Eq. 17 were also determined, and are reported along with the coefficient of regression, R^2, for the linear fit. The above statistics were calculated for:

(1) the GM data base,

(2) each site in the Texas 5-minute mass balance data base for MOBILE1 emission factors,

(3) each site in the Texas 5-minute mass balance data base for the experimentally determined emission factors,

(4) the combined data for all sites in the mass balance data base for the MOBILE1 emission factors,

(5) the combined data for all sites in the mass balance data base for the experimentally determined emission factors,

(6) each site in the Texas 15-minute data base, and

(7) the combined data for all sites in the 15-minute data base.

Since there are many figures and tables, only the major results are discussed here.

GM Data Base. The results for the GM data base, shown in Figure 16 and Table 9, indicate that TRAPS IIM exhibits far better performance than any of the other models. This is to be expected, since the GM data were used to develop this model. All of the other models overpredict more than TRAPS IIM does, which has a value of 0.04 ppb for average error. The probable error for TRAPS IIM is 0.38 ppb, which is half of that for the model with the next smallest value, AIRPOL-4A. The maximum error is about the same for all of the models, except HIWAY, indicating that the most severe underprediction possible is about 2.5 ppb. The coefficient of determination for the linear regression of TRAPS IIM predictions compared with the data is more than twice as large as that for the model with the second largest value, AIRPOL-4A. This indicates that the scatter in the model prediction errors is much less than for any of the other models.

Examination of Figure 16 reveals that the slope and intercept of the linear regressions for TRAPS IIM and AIRPOL-4A are similar. It must be

Table 9. Statistical Results for Comparison of Model Predictions to Data for GM Data Base

Statistic	TRAPS IIM	AIRPOL-4A	CALINE-2	HIWAY	TRAPS II
Avg. error (ppb)	0.041	-0.269	-0.665	-2.108	-0.747
Prob. error (ppb)	0.380	0.729	1.042	2.567	1.599
Avg. squared error (ppb^2)	0.319	1.239	2.827	18.898	6.162
Max. error (ppb)	2.267	2.565	2.196	0.545	2.995
Min. error (ppb)	-2.411	-6.758	-9.688	-49.175	-23.455
R^2	0.56	0.24	0.18	0.25	0.22
Intercept	0.13 ± 0.04	0.43 ± 0.05	0.70 ± 0.09	0.40 ± 0.27	0.06 ± 0.15
Slope	0.82 ± 0.03	0.80 ± 0.05	0.96 ± 0.07	2.92 ± 0.23	1.67 ± 0.12
Number of points	560	962	790	460	708

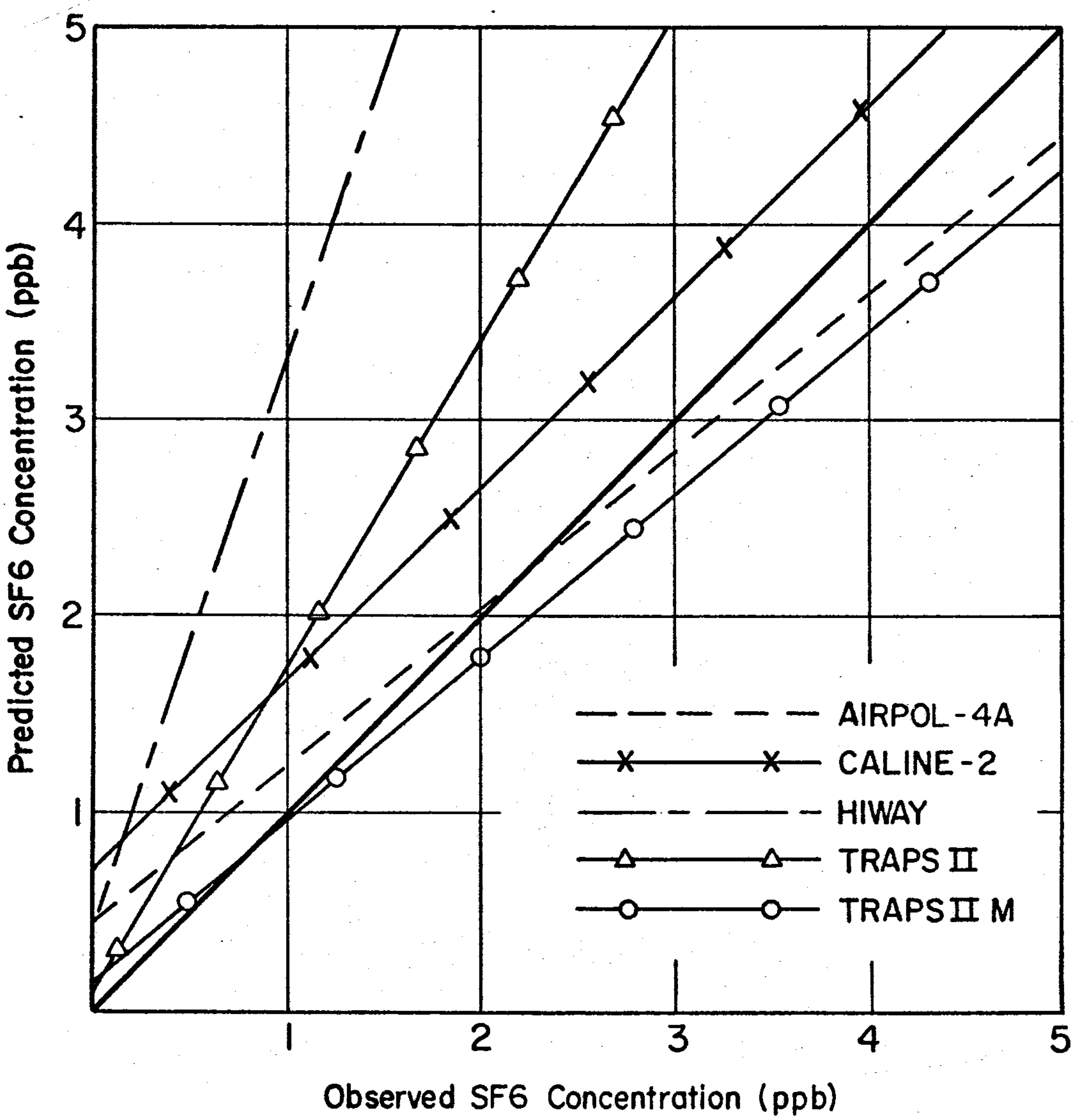

FIGURE 16 Regression Lines of Models for GM Data.

noted, however, that the SF_6 concentrations for the GM data base were almost all less than 2.0 ppb. If the regression lines in Figure 16 are compared for this range of actual concentration, TRAPS IIM clearly approximates the 45° line more closely.

Mass Balance Data Base. For the comparison with the mass balance data, there are four sites, five models, and two emission factor types used. This yields 40 site-model-emission factor combinations for which statistics were calculated. The results of these comparisons are presented in Tables 10-19 and Figures 17-26. A summary of the results of statistical comparisons is presented in Table 20. The comparison is between statistics for model performance for MOBILE1 emission factors and model performance for mass balance emission factors. This comparison indicates that the model performance was significantly improved for the Houston at-grade and El Paso sites when mass balance emission factors were used instead of MOBILE1 emission factors. These sites did not have multiple lane groups, as did the at-grade sites in Dallas and San Antonio.

It is interesting to compare the regression lines graph for MOBILE1 emission factors and the regression lines graph for mass balance emission factors for each site. Such a comparison indicates that the regression lines for almost all model-site combinations approximate the 45° line more closely for the mass balance emission factors case. This result is not apparent for the Dallas at-grade site, since, for that site, the mass balance and MOBILE1 emission factors were of similar magnitude.

The major exception to the above improvement is for HIWAY, for which the regression lines approximate the 45° line better for the MOBILE1 emission factor. The regression lines indicate constant, severe

Table 10. Statistical Results for Comparison of Model Results to Data for Mass Balance Cases, Houston at-Grade Site (MOBILE 1 Emission Factors).

Statistic	TRAPS IIM	AIRPOL-4A	CALINE-2	HIWAY	TRAPS II
Avg. error (ppm)	1.16	0.76	0.93	0.37	1.10
Prob. error (ppm)	0.77	1.16	1.15	1.71	0.67
Avg. sq. error (ppm^2)	2.65	3.51	3.78	6.53	2.20
Max. error (ppm)	4.60	4.93	5.00	3.10	3.91
Min. error (ppm)	-1.30	-5.25	-5.53	-14.41	-1.40
R^2	0.35	0.02	0.02	0.08	0.58
intercept	0.16±0.07	0.89±0.15	0.74±0.15	0.58±0.31	0.11±0.06
slope	0.30±0.03	0.13±0.06	0.12±0.06	0.50±0.13	0.36±0.02
% within ±2 ppm	83	77	71	74	84
% within ±1 ppm	83	34	36	32	41
number of points	179	179	179	179	179

Table 11. Statistical Results of Comparison of Model Results to Data for Mass Balance Cases, Houston at-Grade Site (Mass Balance Emission Factors).

Statistic	TRAPS IIM	AIRPOL-4	CALINE-2	HIWAY	TRAPS II
Avg. error (ppm)	-0.45	-0.73	-0.21	-1.44	-0.79
Prob. error (ppm)	1.15	0.88	0.85	2.23	1.31
Avg. sq. error (ppm^2)	3.12	1.23	1.62	12.96	4.35
Max. error (ppm)	2.50	3.00	2.60	3.10	2.50
Min. error (ppm)	-10.30	-5.25	-6.20	-12.59	-10.70
R^2	0.51	0.46	0.49	0.53	0.59
intercept	0.01±0.21	1.02±0.16	0.48±0.16	0.75±0.36	-0.22±0.23
slope	1.23±0.07	0.85±0.07	0.86±0.07	2.15±0.15	1.53±0.10
% within ± 2 ppm	89	85	91	61	83
% within ± 1 ppm	89	67	69	34	61
number of points	179	179	179	179	179

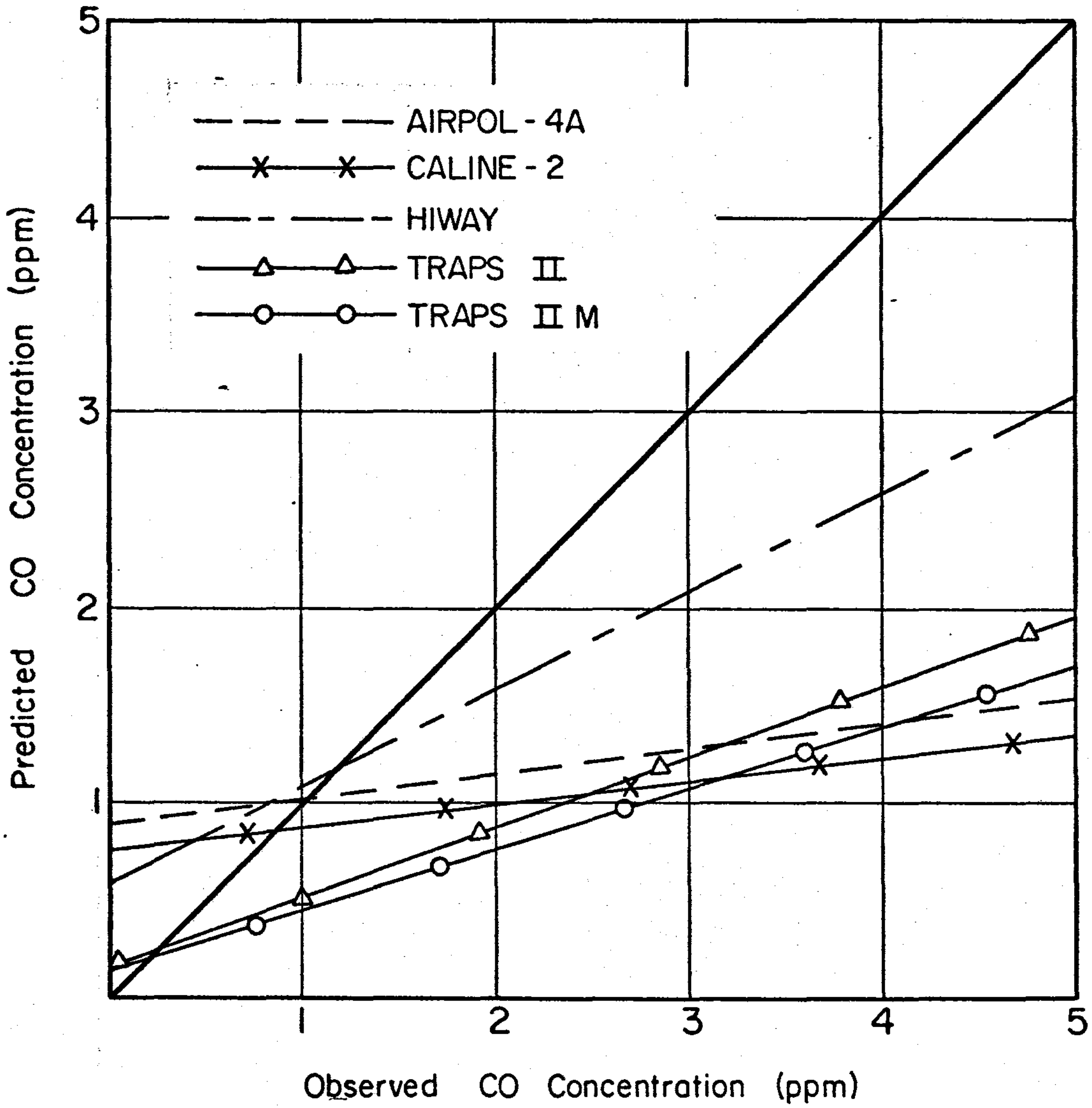

FIGURE 17 Regression Lines of Models for 5-Minute Average Houston at-Grade Data (MOBILE1 Emission Factors).

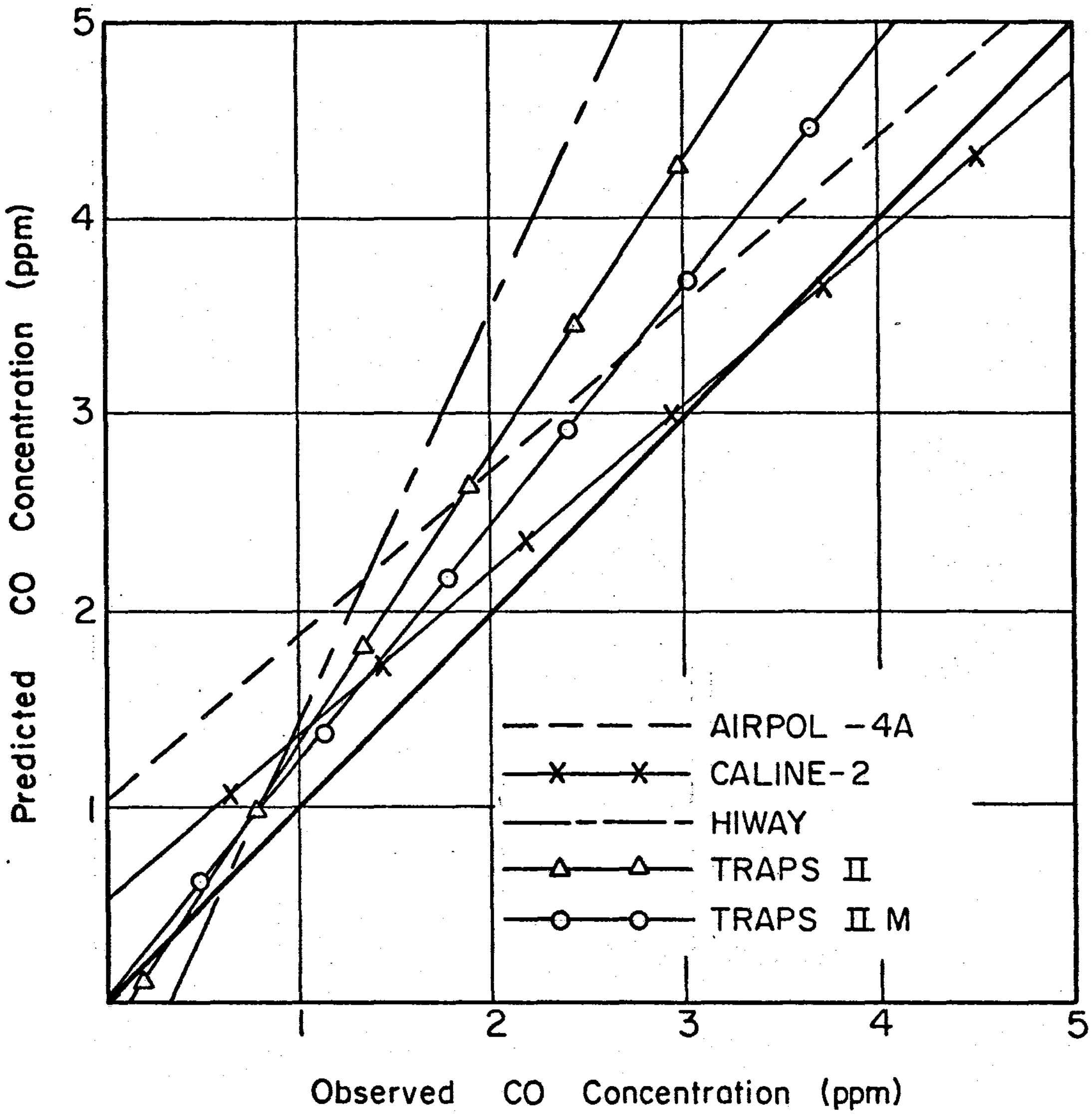

FIGURE 18 Regression Lines of Models for 5-Minute Average Houston at-Grade Data (Mass Balance Emission Factors).

Table 12. Statistical Results of Comparison of Model Results to Data for Mass Balance Cases, Dallas at-Grade Site (MOBILE 1 Emission Factors).

Statistic	TRAPS IIM	AIRPOL-4A	CALINE-2	HIWAY	TRAPS II
Avg. error (ppm)	0.03	0.12	0.29	-0.23	-0.53
Prob. error (ppm)	0.50	0.36	0.37	0.85	1.24
Avg. sq. error (ppm^2)	0.54	0.30	0.39	1.66	3.62
Max. error (ppm)	2.00	1.73	1.91	2.31	2.24
Min. error (ppm)	-2.40	-1.10	-0.98	-4.01	-8.49
R^2	0.30	0.47	0.44	0.20	0.17
intercept	0.23±0.09	0.28±0.05	0.10±0.05	0.33±0.17	0.46±0.25
slope	0.60±0.09	0.43±0.05	0.45±0.05	0.86±0.17	1.10±0.25
% within ± 2 ppm	99	100	100	88	81
% within ± 1 ppm	99	94	91	68	53
number of points	104	104	104	104	104

Table 13. Statistical Results of Comparison of Model Results to Data for Mass Balance Cases, Dallas at-Grade Site (Mass Balance Emission Factors).

Statistic	TRAPS IIM	AIRPOL-4A	CALINE-2	HIWAY	TRAPS II
Avg. error (ppm)	-0.35	-0.24	0.06	-0.82	-1.27
Prob. error (ppm)	0.34	0.41	0.40	1.20	1.72
Avg. sq. error (ppm^2)	0.74	0.43	0.36	3.79	8.01
Max. error (ppm)	1.70	0.99	1.80	2.28	2.20
Min. error (ppm)	-5.50	-2.34	-1.50	-7.94	-9.70
R^2	0.12	0.34	0.36	0.09	0.07
intercept	0.70±0.14	0.66±0.06	0.33±0.06	0.99±0.24	1.29±0.35
slope	0.52±0.14	0.43±0.06	0.47±0.06	0.77±0.24	0.96±0.34
% within ± 2 ppm	94	98	100	76	61
% within ± 1 ppm	94	93	90	51	41
number of points	104	104	104	104	104

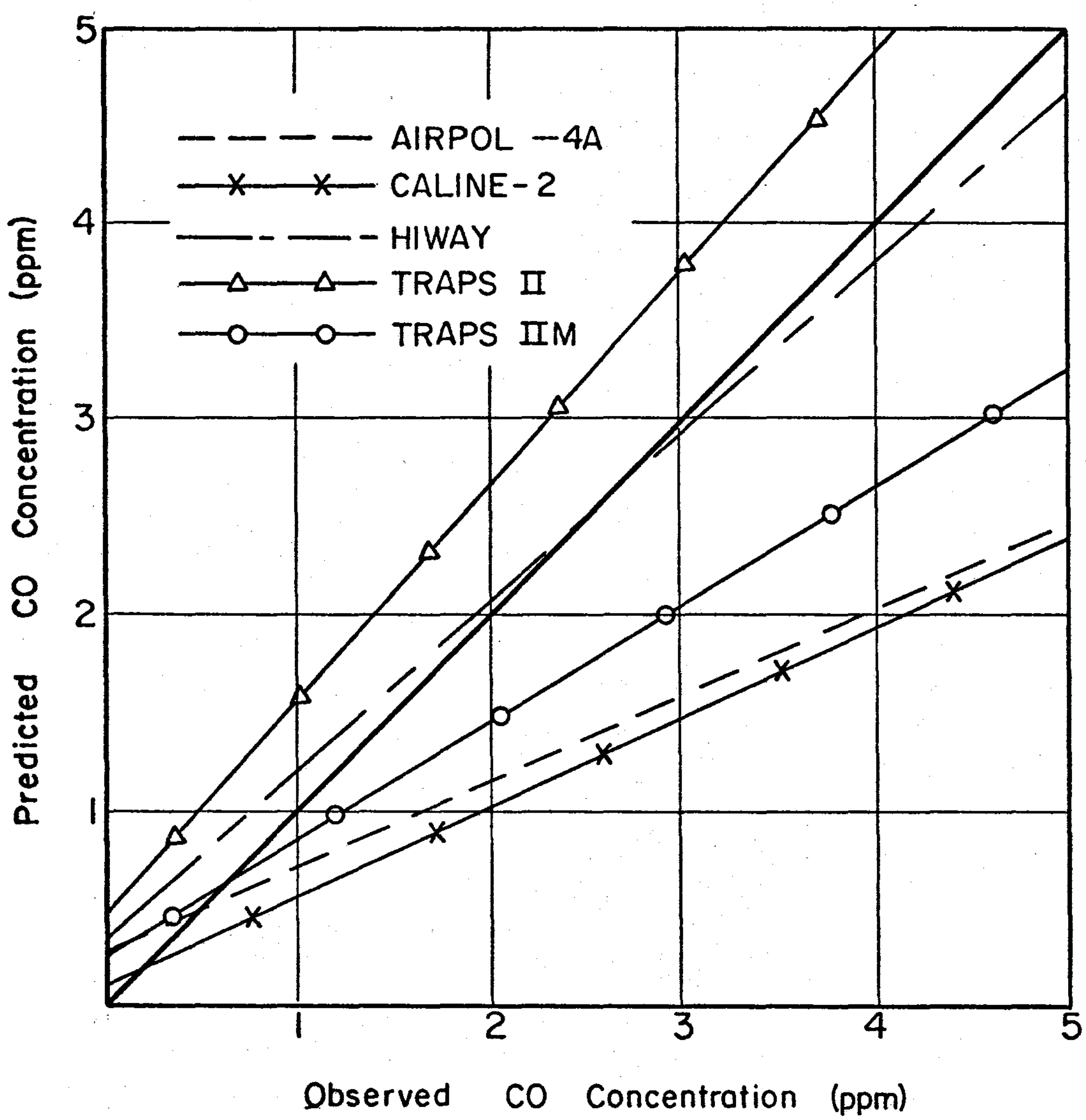

FIGURE 19 Regression Lines of Models for 5-Minute Average Dallas at-Grade Data (MOBILE1 Emission Factors.)

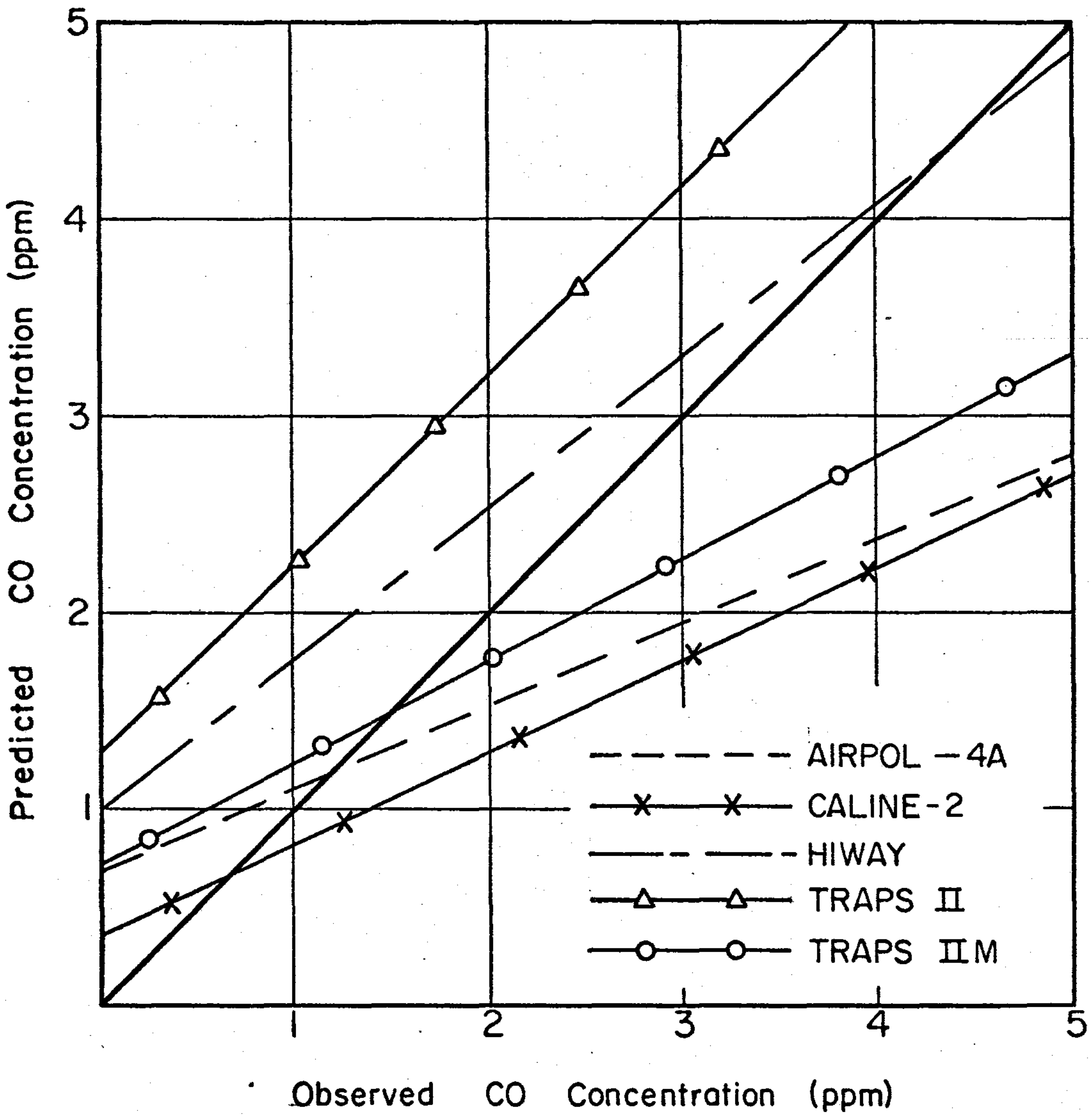

FIGURE 20 Regression Lines of Models for 5-Minute Average Dallas at-Grade Data (Mass Balance Emission Factors).

Table 14. Statistical Results of Comparison of Model Results to Data for Mass Balance Cases, San Antonio Site (MOBILE 1 Emission Factors).

Statistic	TRAPS IIM	AIRPOL-4A	CALINE-2	HIWAY	TRAPS II
Avg. error (ppm)	-0.06	-0.22	0.16	-0.59	-0.27
Prob. error (ppm)	0.39	0.34	0.39	0.61	0.39
Avg. sq. error (ppm^2)	0.34	0.30	0.35	1.17	0.34
Max. error (ppm)	1.30	1.21	1.69	1.26	1.30
Min. error (ppm)	-1.30	-1.43	-1.48	-2.56	-1.30
R^2	0.27	0.49	0.23	0.21	0.27
intercept	0.46±0.06	0.71±0.03	0.39±0.03	0.80±0.12	0.46±0.06
slope	0.41±0.06	0.29±0.03	0.19±0.03	0.69±0.12	0.41±0.06
% within ± 2 ppm	100	100	100	91	100
% within ± 1 ppm	100	90	90	66	100
number of points	117	117	117	117	117

Table 15. Statistical Results of Comparison of Model Results to Data for Mass Balance Cases, San Antonio Site (Mass Balance Emission Factors).

Statistic	TRAPS IIM	AIRPOL-4A	CALINE-2	HIWAY	TRAPS II
Avg. error (ppm)	-0.27	-0.49	-0.00	-0.96	-0.54
Prob. error (ppm)	0.50	0.45	0.41	1.04	0.77
Avg. sq. error (ppm^2)	0.63	0.67	0.37	3.27	1.60
Max. error (ppm)	1.30	1.48	1.80	0.91	1.30
Min. error (ppm)	-2.70	-2.37	-1.60	-6.91	-4.20
R^2	0.26	0.25	0.20	0.18	0.17
intercept	0.51±0.10	0.81±0.08	0.47±0.06	0.89±0.21	0.68±0.15
slope	0.65±0.10	0.52±0.08	0.31±0.06	1.11±0.22	0.80±0.16
% within ± 2 ppm	98	98	100	84	89
% within ± 1 ppm	98	77	92	65	68
number of points	117	117	117	117	117

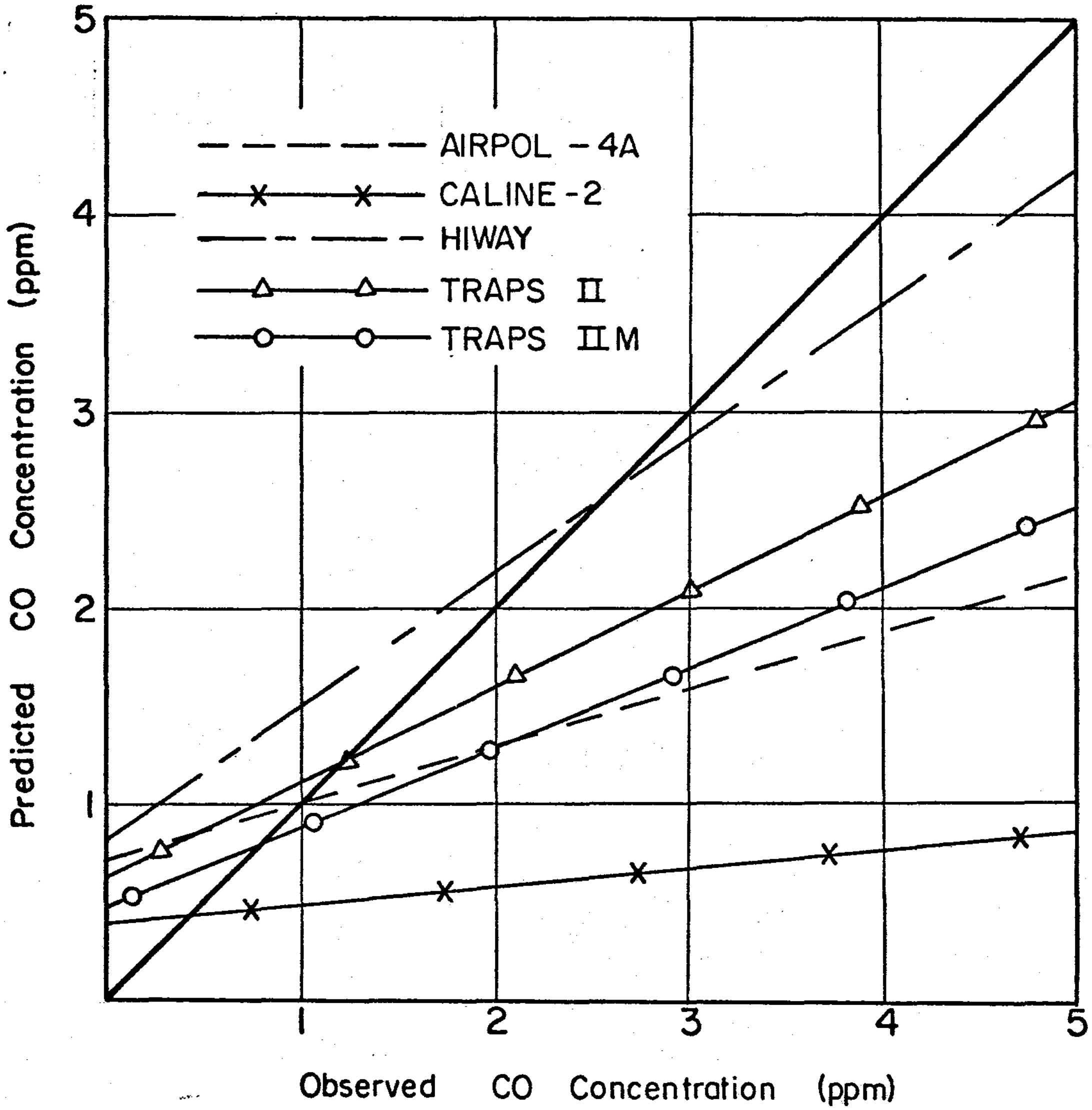

FIGURE 21 Regression Lines of Models for 5-Minute Average San Antonio Data (MOBILE1 Emission Factors).

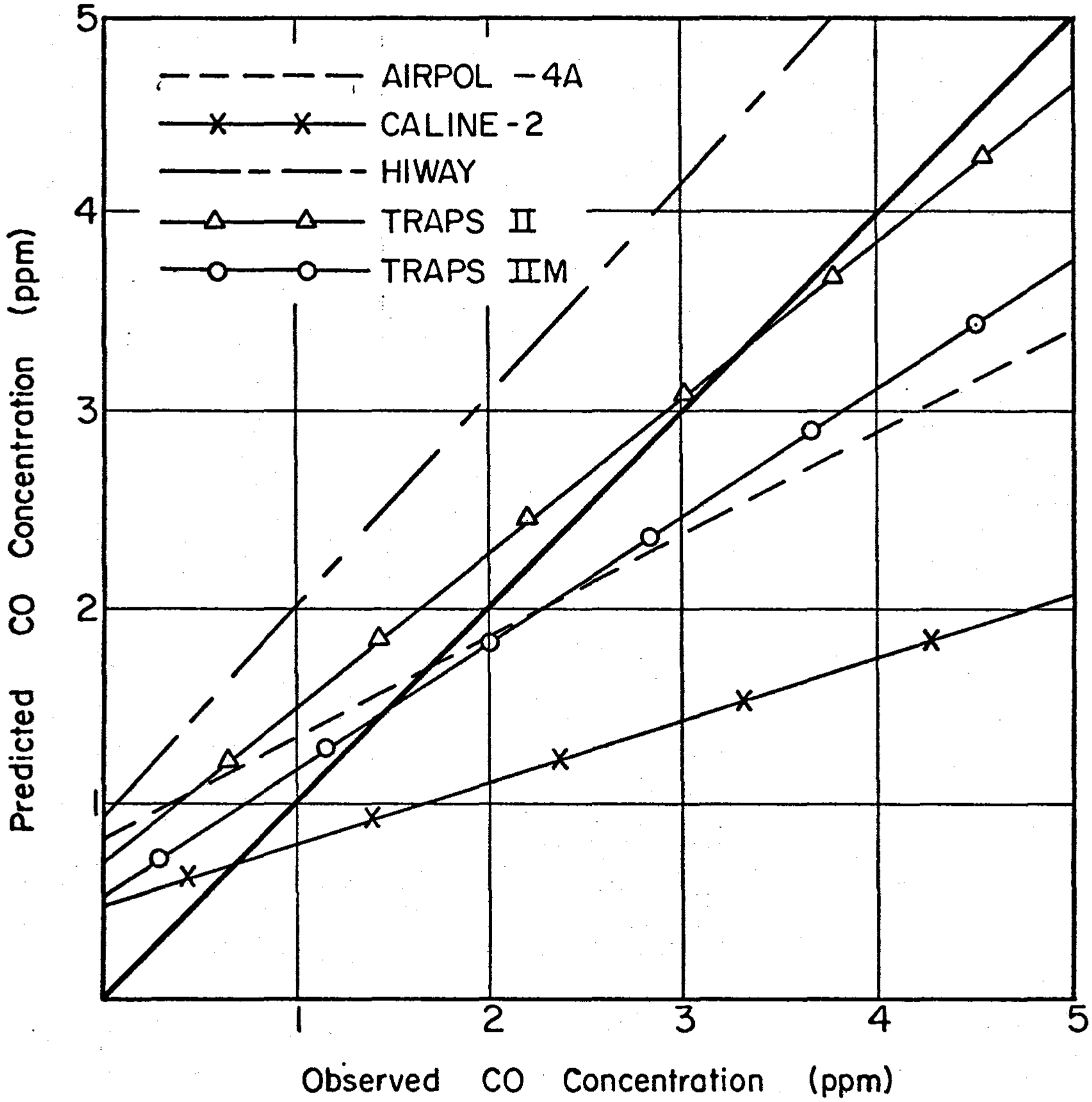

FIGURE 22 Regression Lines of Models for 5-Minute Average San Antonio Data (Mass Balance Emission Factors).

Table 16. Statistical Results of Comparison of Model Results to Data for Mass Balance Cases, El Paso Site (MOBILE 1 Emission Factors).

Statistic	TRAPS IIM	AIRPOL-4A	CALINE-2	HIWAY	TRAPS II
Avg. error (ppm)	0.98	0.82	0.76	-0.33	0.79
Prob. error (ppm)	0.60	0.65	0.78	1.59	0.59
Avg. sq. error (ppm^2)	1.76	1.60	1.90	5.63	1.38
Max. error (ppm)	3.80	3.94	4.00	3.07	2.90
Min. error (ppm)	-1.80	-3.02	-4.50	-13.13	-2.20
R^2	0.56	0.48	0.22	0.27	0.52
intercept	0.05±0.04	0.30±0.04	0.29±0.08	0.12±0.25	-0.02±0.07
slope	0.36±0.02	0.29±0.02	0.34±0.04	1.13±0.12	0.52±0.03
% within ± 2 ppm	90	93	90	77	94
% within ± 1 ppm	52	52	53	40	59
number of points	240	240	240	240	240

Table 17. Statistical Results of Comparison of Model Results to Data for Mass Balance Cases, El Paso Site (Mass Balance Emission Factors).

Statistic	TRAPS IIM	AIRPOL-4	CALINE-2	HIWAY	TRAPS II
Avg. error (ppm)	-0.21	-0.73	-0.83	-4.07	-0.68
Prob. error (ppm)	0.66	0.65	0.93	4.53	0.97
Avg. sq. error (ppm^2)	0.99	1.45	2.60	61.50	2.52
Max. error (ppm)	1.70	1.68	2.06	3.01	1.84
Min. error (ppm)	-3.90	-4.26	-10.28	-23.00	-6.64
R^2	0.63	0.57	0.41	0.33	0.64
intercept	0.17±0.10	0.93±0.10	0.94±0.15	0.22±0.63	-0.01±0.14
slope	1.02±0.05	0.87±0.05	0.93±0.07	3.41±0.31	1.43±0.07
% within ± 2 ppm	94	90	87	50	82
% within ± 1 ppm	80	58	67	35	70
number of points	240	240	240	240	240

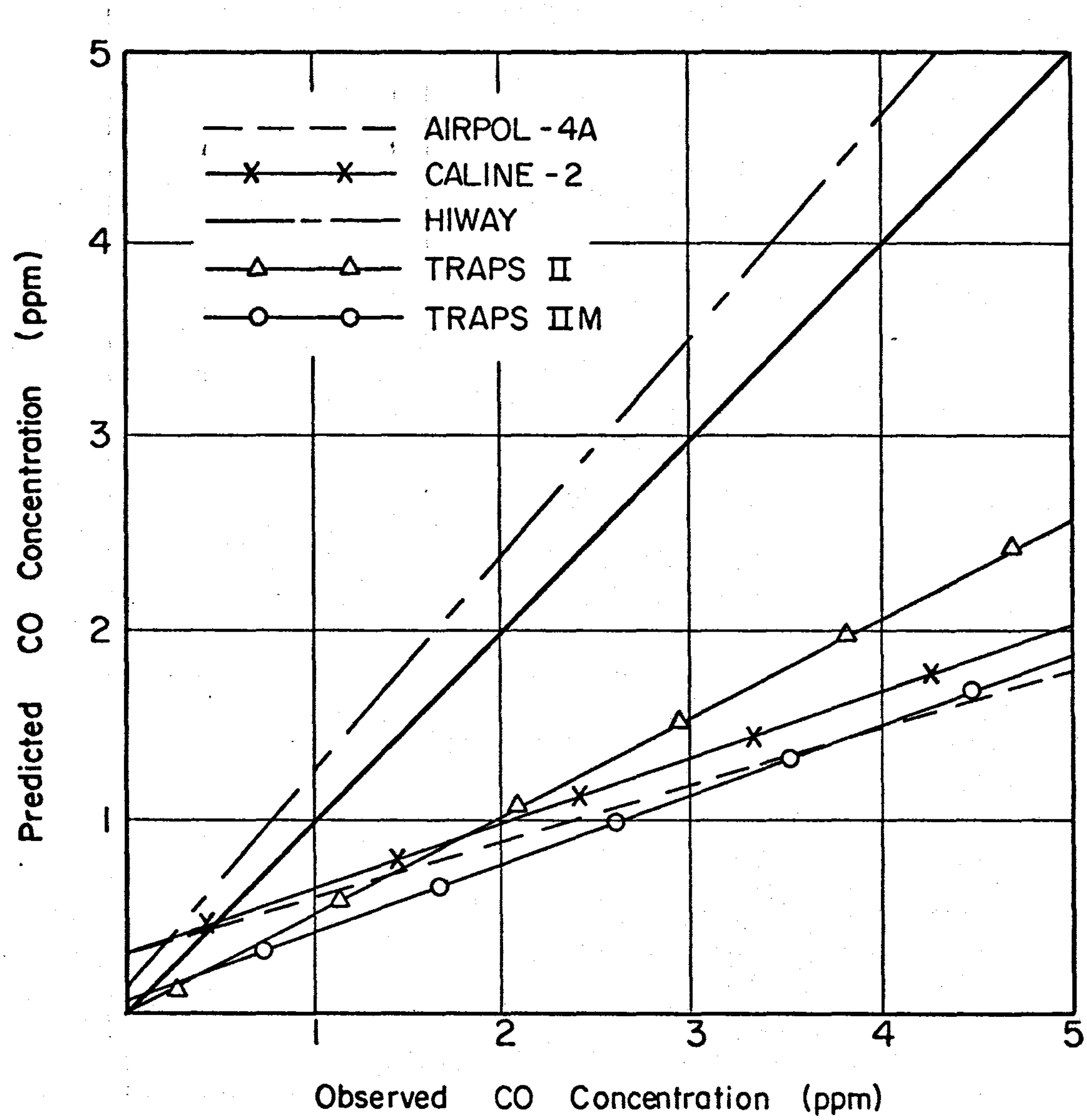

FIGURE 23 Regression Lines of Models for 5-Minute Average El Paso Data (MOBILE1 Emission Factors).

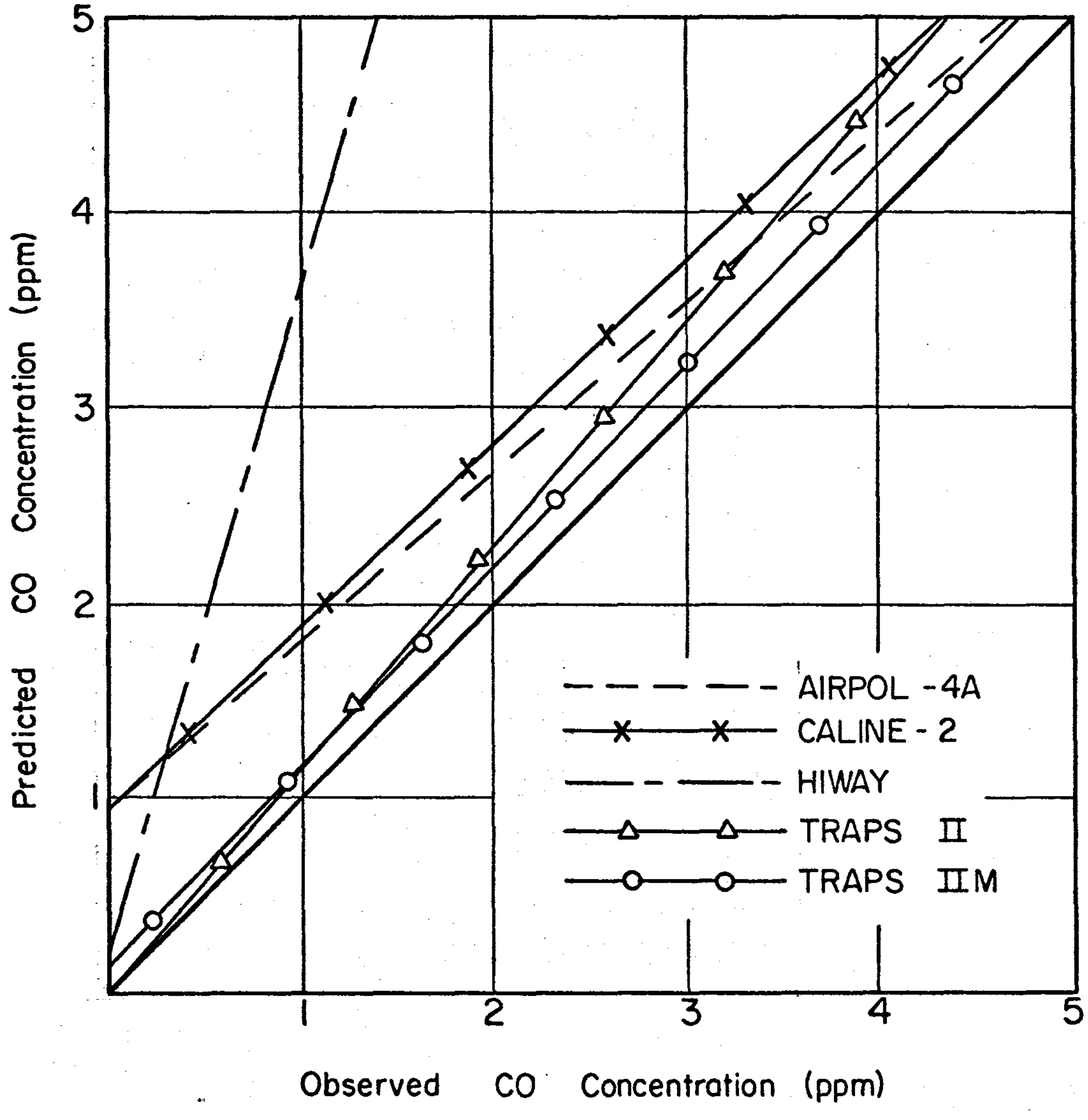

FIGURE 24 Regression Lines of Models for 5-Minute Average El Paso Data (Mass Balance Emission Factors).

Table 18. Statistical Results of Comparison of Model Results to Data for Mass Balance Cases, Combined Data for Texas at-Grade Sites (MOBILE 1 Emission Factors).

Statistic	TRAPS IIM	AIRPOL-4A	CALINE-2	HIWAY	TRAPS II
Avg. error (ppm)	0.69	0.50	0.62	-0.16	0.47
Prob. error (ppm)	0.70	0.81	0.83	1.41	0.86
Avg. Squared error (ppm^2)	1.55	1.68	1.90	4.42	1.85
Max. error (ppm)	4.60	4.93	5.00	3.10	3.91
Min. error (ppm)	-2.40	-5.25	-5.53	-14.41	-8.49
R^2	0.48	0.14	0.14	0.17	0.17
intercept	0.34±0.10	0.55±0.04	0.38±0.05	0.49±0.12	0.40±0.06
slope	0.29±0.02	0.23±0.02	0.27±0.03	0.77±0.07	0.37±0.03
% within ± 2 ppm	91	91	88	80	90
% within ± 1 ppm	77	61	61	47	56
number of points	640	640	640	640	640

Table 19. Statistical Results of Comparison of Model Results to Data for Mass Balance Cases, Combined Data for Texas at-Grade Sites (Mass Balance Emission Factors).

Statistic	TRAPS IIM	AIRPOL-4A	CALINE-2	HIWAY	TRAPS II
Avg. error (ppm)	-0.31	-0.60	-0.36	-2.24	-0.78
Prob. error (ppm)	0.82	0.67	0.81	3.23	1.20
Avg. Squared error (ppm^2)	1.57	1.36	1.55	27.90	3.75
Max. error (ppm)	2.50	3.00	2.60	3.10	2.50
Min. error (ppm)	-10.30	-5.25	-10.28	-23.00	-10.70
R^2	0.54	0.56	0.49	0.34	0.48
intercept	0.24±0.07	0.75±0.06	0.46±0.07	0.14±0.26	0.34±0.10
slope	1.05±0.04	0.89±0.03	0.93±0.04	2.53±0.14	1.32±0.05
% within ± 2 ppm	94	91	92	64	80
% within ± 1 ppm	88	70	76	42	63
number of points	640	640	640	640	640

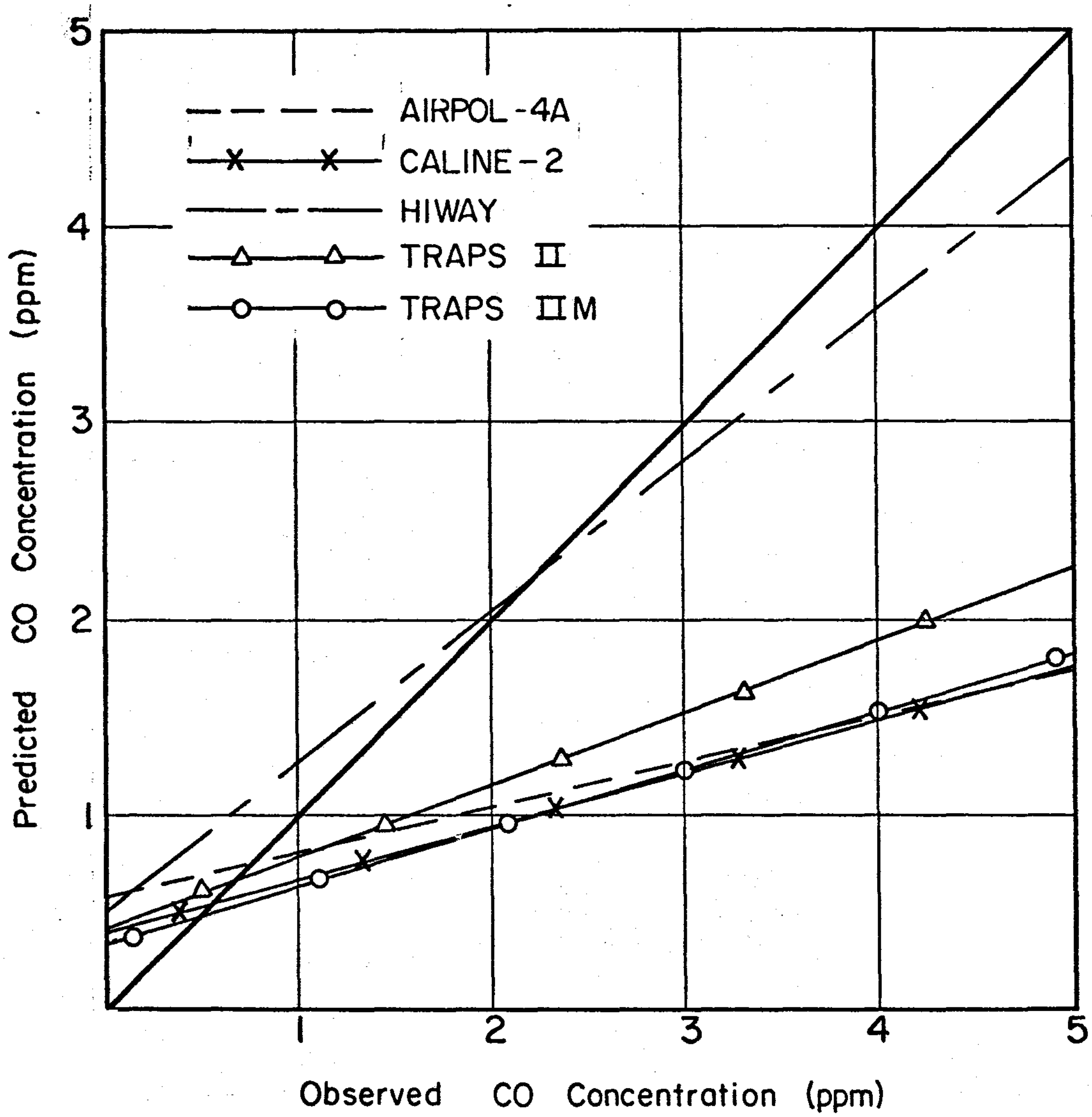

FIGURE 25 Regression Lines of Models for Combined 5-Minute Average Texas Data (MOBILE1 Emission Factors).

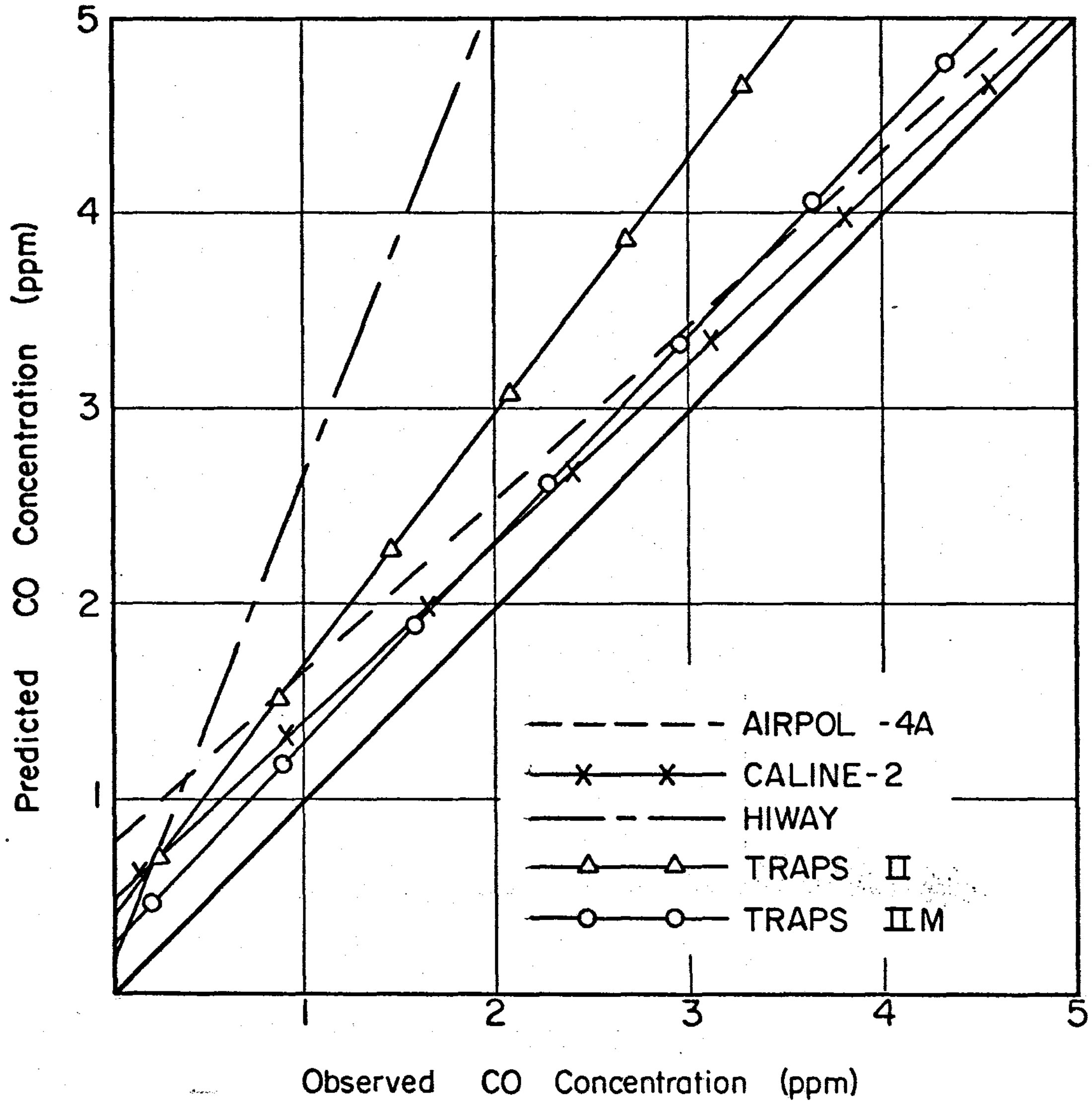

FIGURE 26 Regression Lines of Models for Combined 5-Minute Average Texas Data (Mass Balance Emission Factors)

Table 20. Summary of Results of Comparison of Performance Statistics for the Mass Balance Data Base

Site	Models with Improved Avg. error	Models with Improved Possible Error	Models with Improved Max. Error	Models with Improved Min. Error	Models with Improved R^2	Models with Improved % within ± 2 ppm	Models with Improved % within ± 2 ppm
Houston At-Grade	CALINE-2 TRAPS II TRAPS IIM	AIRPOL-4A CALINE-2	AIRPOL-4A CALINE-2 TRAPS II	HIWAY	AIRPOL-4A CALINE-2 HIWAY	AIRPOL-4A CALINE-2 TRAPS IIM	AIRPOL-4A CALINE-2 TRAPS II TRAPS IIM
Dallas At-Grade	CALINE-2	TRAPS IIM	AIRPOL-4A TRAPS IIM				
San Antonio	CALINE-2		HIWAY				
El Paso	AIRPOL-4A TRAPS II TRAPS IIM		AIRPOL-4A CALINE-2 TRAPS II TRAPS IIM		AIRPOL-4A CALINE-2 HIWAY TRAPS II TRAPS IIM		AIRPOL-4A CALINE-2 TRAPS II TRAPS IIM
Combined Sites	CALINE-2 TRAPS IIM	AIRPOL-4A	AIRPOL-4A CALINE-2 HIWAY TRAPS II TRAPS IIM		AIRPOL-4A CALINE-2 HIWAY TRAPS II TRAPS IIM		AIRPOL-4A CALINE-2 TRAPS II TRAPS IIM

Improvement indicates better statistic for mass balance emission factors overprediction for HIWAY using the mass balance emission factors. The tendency for HIWAY to predict higher concentrations than the other models was indicated by Noll et al. (1978). The general trend of overprediction for HIWAY was also reported by Chock (1977) in a comparison with the GM data.

Perhaps the most important comparison that may be made for the mass balance data base is a comparison of the statistics for the combined data base using mass balance emission factors to the statistics for the GM data base. One should be cognizant of the fact that the emission factor for the GM data base was well defined and measured. Since the objective pollutants and their concentrations are much different for the two data bases, the error statistics are difficult to compare. However, the regression statistics for the two analyses are remarkably similar. This may be demonstrated by comparing the graphs of the regression lines for the two data bases in Figures 16 and 26.

Both of the graphs show that HIWAY and TRAPS II exhibit overprediction constantly, and the magnitudes of this error trend are of the same order for each of the data bases. Both graphs also indicate that the other models' regression lines form a closely related group for both data bases. Within these groups, the lines are nearly parallel and are within one concentration unit (ppb or ppm) for the range of the graph values.

The regression coefficient, R^2, for the lines may be compared for each model between the two data bases. This comparison shows that R^2 is much greater for the mass balance data than for the GM data for all of the models, except TRAPS IIM, for which the two values are equal.

This is a rather remarkable result since R^2 is an indication of scatter about the regression line. For nearly identical regression lines, the GM model results would be expected to have less scatter than the Texas mass balance model results. This is especially true, since the GM emission factors were controlled and measured and the Texas mass balance emission factors were calculated from experimental measurements of random variables.

All of the above clearly indicates that the mass balance emission factor method is reliable. Comparison of the statistics for the combined Texas mass balance emission factor results and the statistics for the MOBILE1 emission factor results shows that model performance is much better for the mass balance emission factors. Therefore, the MOBILE1 emission factors must be considered suspect, at least.

For this reason, the statistics from the model comparison with the calculated emission factors are used as indicators for comparison of model performance. These statistics are for the combined sites and are given in Table 19 and Figure 26. TRAPS IIM exhibits the smallest average error (in absolute value), smallest maximum error (equal to that for TRAPS II), and most predictions within both ± 2 ppm and ± 1 ppm. TRAPS IIM's performance with respect to probable error is surpassed by AIRPOL-4A, with a value of 0.67 ppm compared to 0.82 for TRAPS IIM and CALINE-2. The minimum error is similar for all models (about -10.5 ppm), except for HIWAY and AIRPOL-4A. These two models exhibit much greater overprediction. TRAPS II and HIWAY do not perform well with respect to the regression line analysis. The regression lines for the other models all approximate the 45° line well. It should be noted, however, that among the models AIRPOL-4A, CALINE-2, and TRAPS IIM have intercepts close to zero and slopes close to one, which are the ideal values. TRAPS IIM also exhibits the least scatter (along with AIRPOL-4A), as is reflected by the largest value for R^2.

Texas 15-minute Average Data Base. The above analysis of the statistical results for the mass balance data base imparts a degree of suspicion to any model evaluation carried out using MOBILE1 emission factors.

It has already been shown that there is a significant difference in model performances when experimentally calculated emission factors are used instead of MOBILE1 emission factors. This is evident in the comparisons for the mass balance data. If it is assumed that this difference also holds for the 15-minute cases, then model performances may be compared and evaluated by inference using the 15-minute results, which were obtained with the use of MOBILE1 emission factors.

Again, as for the mass balance cases, there are many model-site combinations, and any analysis must take into account the relationship between mass balance emission factor results and MOBILE1 emission factor results. The results for the 15-minute cases are presented in Tables 21-27 and Figures 27-33.

Any analysis of results for the model predictions should be for emission factors that are as close as possible to the mass balance emission factor values. In the mass balance data base, the MOBILE1 and mass balance emission factors were most similar for the Dallas at-grade site. However, upon inspection of the regression lines in Figure 28 for the 15-minute average model predictions for this site, it is seen that all

Table 21. Statistical Results for Comparison of Model Predictions to Data for 15-minute Average Houston at-Grade Data.

Statistic	TRAPS IIM	AIRPOL-4A	CALINE-2	HIWAY	TRAPS II
Avg. error (ppm)	0.53	0.09	0.00	-0.12	0.05
Prob. error (ppm)	0.60	0.71	0.88	0.92	0.66
Avg. squared error (ppm^2)	1.08	1.12	1.67	1.87	1.19
Max. error (ppm)	3.05	2.79	2.86	3.05	3.34
Min. error (ppm)	-1.40	-2.93	-3.74	-3.67	-1.76
R^2	0.48	0.31	0.21	0.36	0.37
intercept	0.25±0.06	0.70±0.08	0.73±0.12	0.39±0.15	0.43±0.06
slope	0.43±0.03	0.43±0.05	0.47±0.07	0.81±0.08	0.34±0.03
% within ± 2 ppm	97	95	89	88	96
% within ± 1 ppm	64	64	57	54	61
number of points	195	195	195	195	195

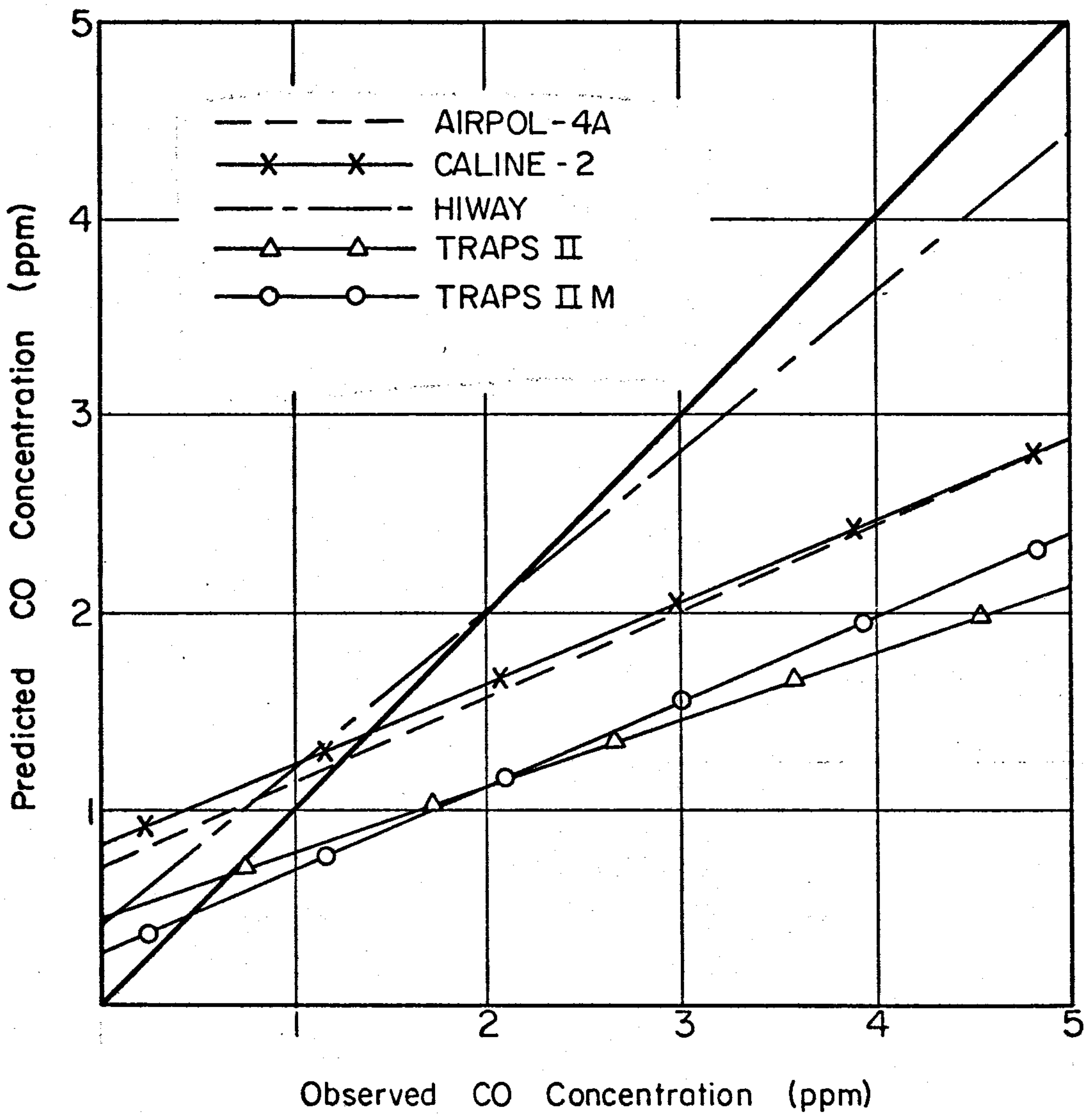

FIGURE 27 Regression Lines of Models for 15-Minute Average Houston at-Grade Data.

Table 22. Statistical Results for Comparison of Model Predictions to Data for 15-Minute Average Dallas at-Grade Data.

Statistic	TRAPS IIM	AIRPOL-4A	CALINE-2	HIWAY	TRAPS II
Avg. error (ppm)	0.43	0.50	0.63	0.35	0.30
Prob. error (ppm)	0.71	0.60	0.62	0.75	0.85
Avg. Squared error (ppm^2)	1.27	1.04	1.22	1.33	1.65
Max. error (ppm)	3.05	2.91	3.05	3.04	3.05
Min. error (ppm)	-1.60	-1.00	-0.88	-1.76	-2.17
R^2	0.17	0.02	0.30	0.16	0.14
intercept	0.49±0.04	0.31±0.02	0.21±0.01	0.61±0.05	0.72±0.08
slope	-0.15±0.04	-0.02±0.01	-0.05±0.01	-0.19±0.05	-0.27±0.07
% within ± 2 ppm	92	92	92	92	90
% within ± 1 ppm	70	76	72	63	50
number of points	98	98	98	98	98

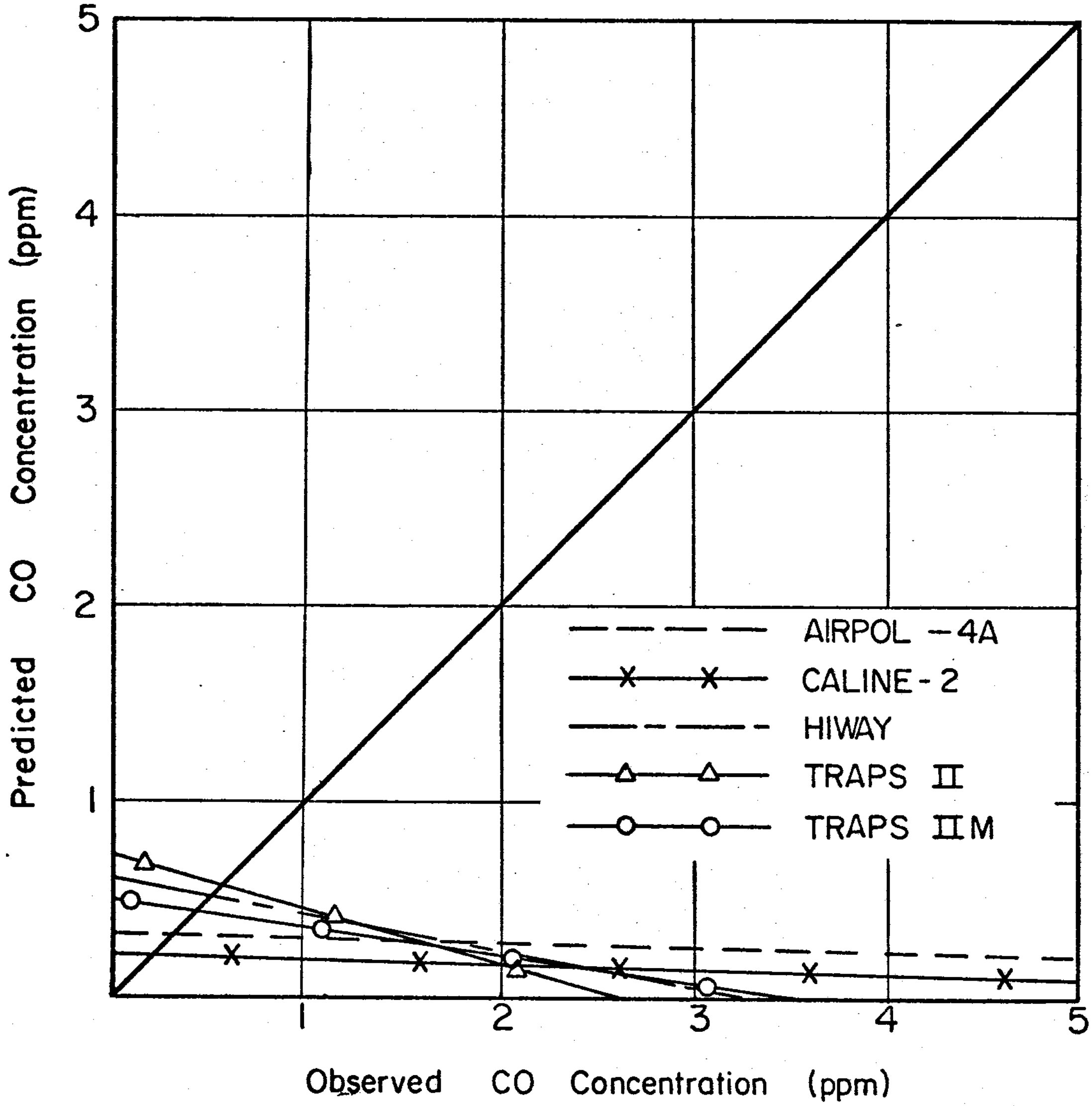

FIGURE 28 Regression Lines of Models for 15-Minute Average Dallas at-Grade Data.

Table 23. Statistical Results for Comparison of Model Predictions to Data for 15-Minute Average San Antonio Data.

Statistic	TRAPS IIM	AIRPOL-4A	CALINE-2	HIWAY	TRAPS II
Avg. error (ppm)	-0.29	-0.66	0.22	-0.19	-0.31
Prob. error (ppm)	0.93	0.59	0.61	1.04	0.95
Avg. Squared error (ppm^2)	1.57	0.76	0.85	2.38	2.09
Max. error (ppm)	2.75	2.40	2.83	4.53	3.00
Min. error (ppm)	-4.80	-2.31	-2.34	-4.74	-13.08
R^2	0.31	0.30	0.30	0.18	0.21
intercept	0.58±0.10	0.89±0.04	0.53±0.05	0.61±0.12	0.70±0.11
slope	0.77±0.06	0.34±0.03	0.41±0.03	0.66±0.08	0.69±0.07
% within ± 2 ppm	88	97	97	81	88
% within ± 1 ppm	69	78	74	53	64
number of points	352	352	352	352	352

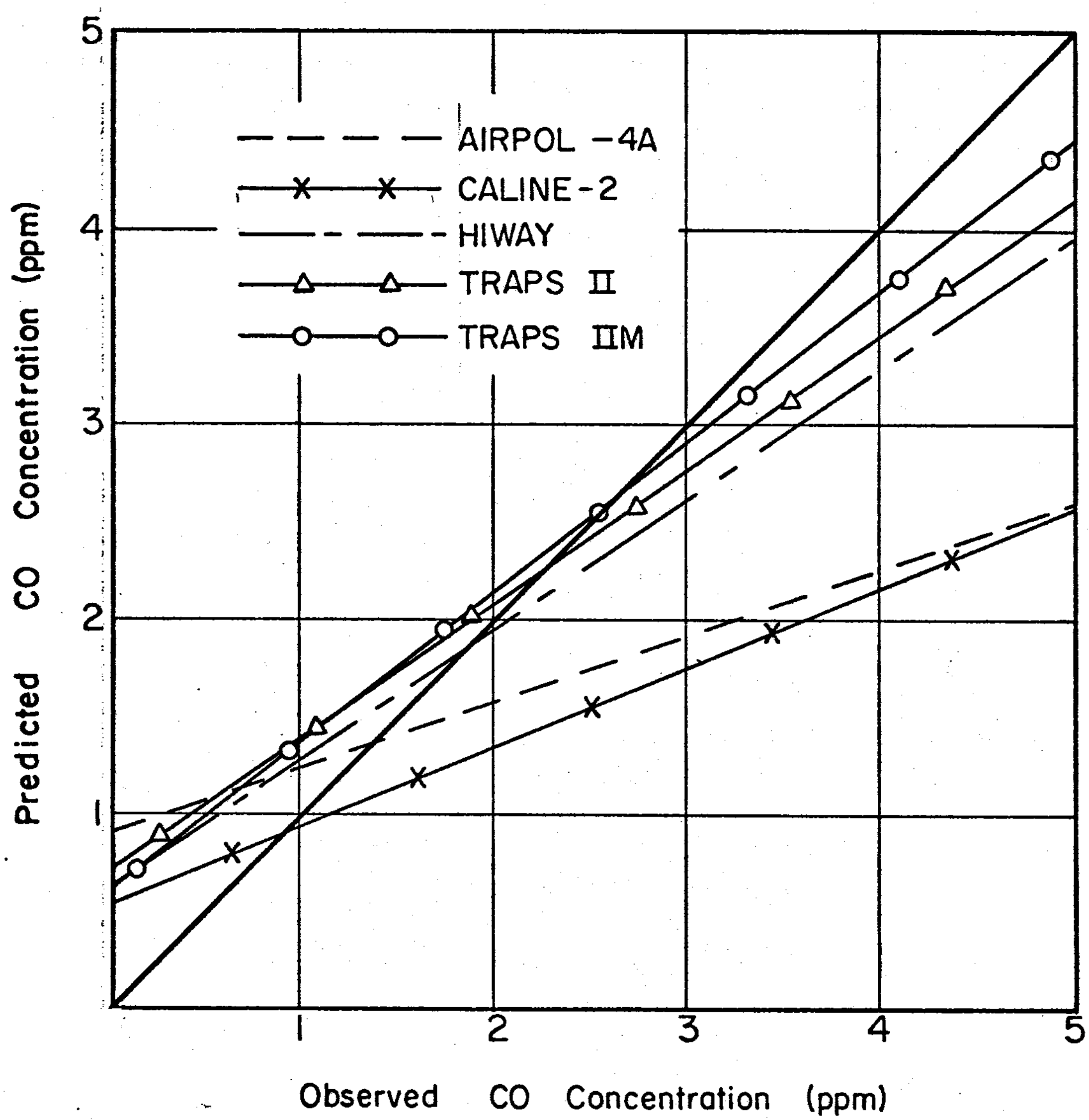

FIGURE 29 Regression Lines of Models for 15-Minute Average San Antonio Data.

Table 24. Statistical Results of Comparison of Model Predictions to Data for 15-minute Average El Paso at-Grade Data.

Statistic	TRAPS IIM	AIRPOL-4A	CALINE-2	HIWAY	TRAPS II
Avg. error (ppm)	0.37	0.23	0.06	-1.57	0.25
Prob. error (ppm)	1.09	1.12	1.05	2.92	1.15
Avg. Squared error (ppm^2)	2.76	2.79	2.43	21.11	2.94
Max. error (ppm)	6.50	6.70	5.58	7.60	6.72
Min. error (ppm)	-5.56	-4.15	-5.10	-28.14	-9.97
R^2	0.37	0.35	0.42	0.03	0.33
intercept	0.58±0.04	0.77±0.04	0.70±0.05	2.47±0.19	0.56±0.06
slope	0.33±0.02	0.29±0.02	0.46±0.02	0.35±0.08	0.42±0.02
% within ± 2 ppm	80	80	83	46	78
% within ± 1 ppm	48	47	51	24	48
number of points	704	704	704	704	704

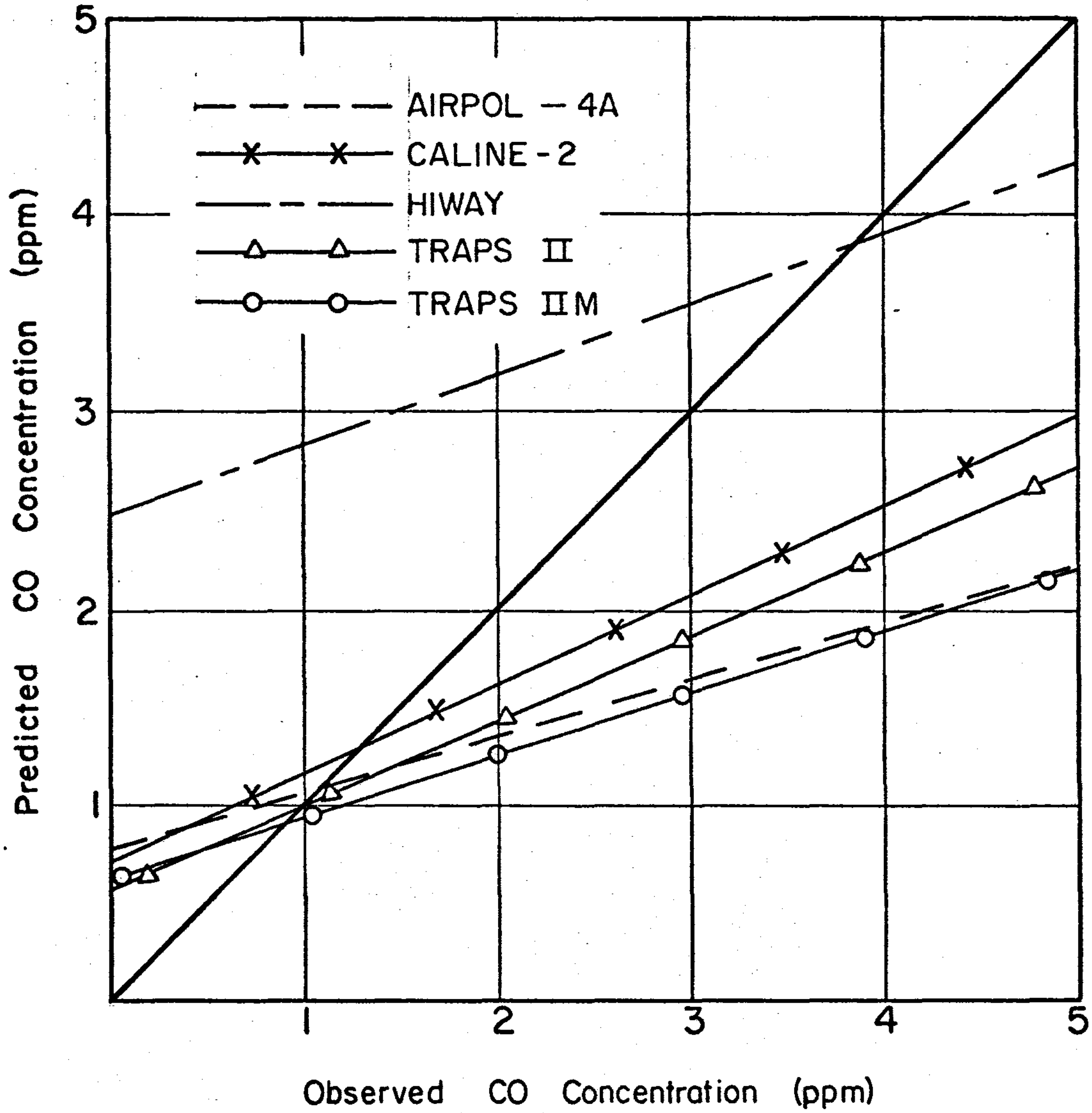

FIGURE 30 Regression Lines of Models for 15-Minute Average El Paso Data.

Table 25. Statistical Results for Comparison of Model Predictions to Data for 15-Minute Average Houston Cut Data.

Statistic	TRAPS IIM	AIRPOL-4A	CALINE-2	HIWAY	TRAPS II
Avg. error (ppm)		-2.15	-1.27	-1.08	
Prob. error (ppm)		1.91	1.29	0.56	
Avg. Squared error (ppm^2)		12.64	5.21	1.86	
Max. error (ppm)		2.90	4.23	1.98	
Min error (ppm)		-1.45	-7.50	-3.32	
R^2		0.15	0.21	0.00	
intercept		2.34±0.17	1.71±0.16	1.27±0.08	
slope		0.73±0.10	0.58±0.09	0.06±0.12	
% within ± 2 ppm		59	72	91	
% within ± 1 ppm		42	56	40	
number of points		329	170	75	

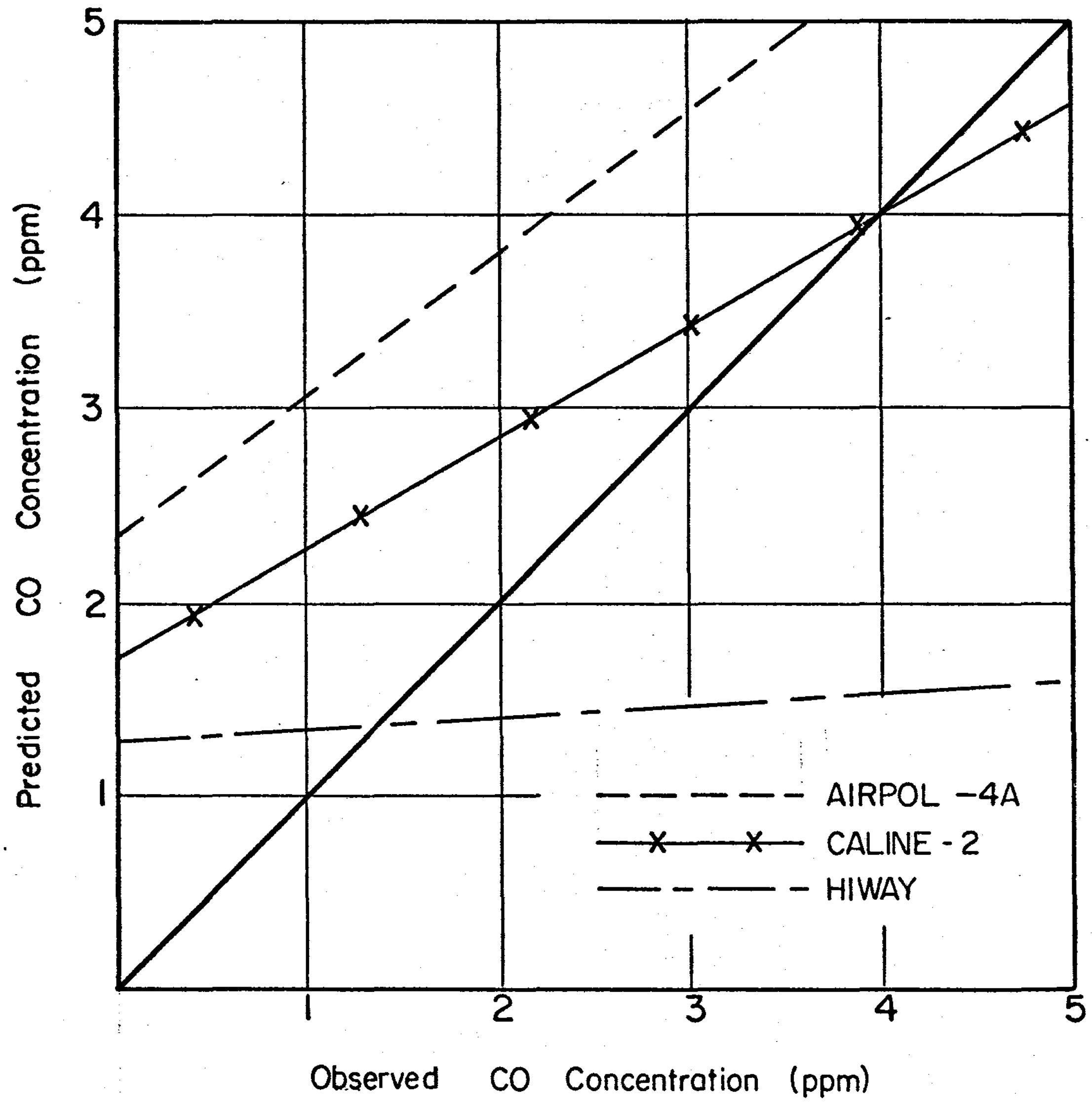

FIGURE 31 Regression Lines of Models for 15-Minute Average Houston Cut Data.

Table 26. Statistical Results for Comparison of Model Predictions to Data for 15-Minute Average Dallas Elevated Data.

Statistic	TRAPS IIM	AIRPOL-4A	CALINE-2	HIWAY	TRAPS II
Avg. error (ppm)		-0.66	-0.26		
Prob. error (ppm)		0.54	0.56		
Avg. Squared error (ppm^2)		1.06	0.75		
Max. error (ppm)		3.42	3.75		
Min. error (ppm)		-3.56	-3.95		
R^2		0.21	0.10		
intercept		0.81±0.02	0.45±0.02		
slope		0.32±0.03	0.16±0.02		
% within ± 2 ppm		96	97		
% within ± 1 ppm		67	84		
number of points		587	587		

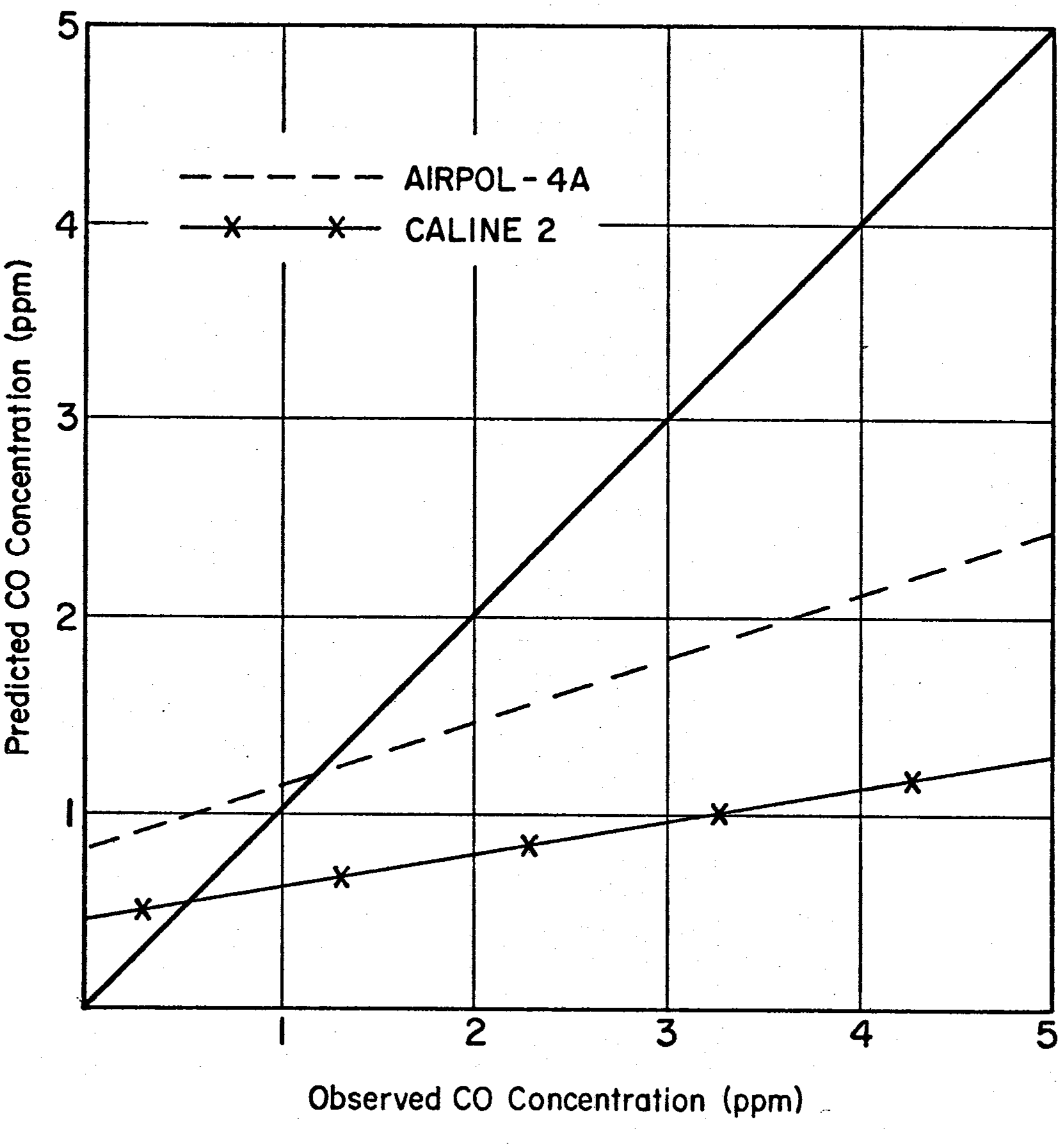

FIGURE 32 Regression Lines of Models for 15-Minute Average Dallas Elevated Data.

Table 27. Statistical Results for Comparison of Model Predictions to Data for Combined Texas 15-Minute Average Data.

Statistic	TRAPS IIM	AIRPOL-4A	CALINE-2	HIWAY	TRAPS II
Avg. error (ppm)	0.22	-0.39	-0.09	-0.87	0.14
Prob. error (ppm)	0.97	1.18	0.90	2.21	1.04
Avg. Squared error (ppm^2)	2.10	3.24	1.80	11.47	2.37
Max. error (ppm)	6.50	6.70	5.58	7.60	6.72
Min. error (ppm)	-5.55	-14.50	-7.50	-28.14	-13.08
R^2	0.28	0.12	0.13	0.05	0.26
intercept	0.60±0.02	1.01±0.04	0.62±0.03	1.56±0.11	0.61±0.04
slope	0.37±0.02	0.34±0.02	0.46±0.01	0.45±0.05	0.43±0.02
% within ± 2 ppm	85	86	89	66	84
% within ± 1 ppm	58	59	66	39	54
number of points	1349	2265	2107	1424	1349

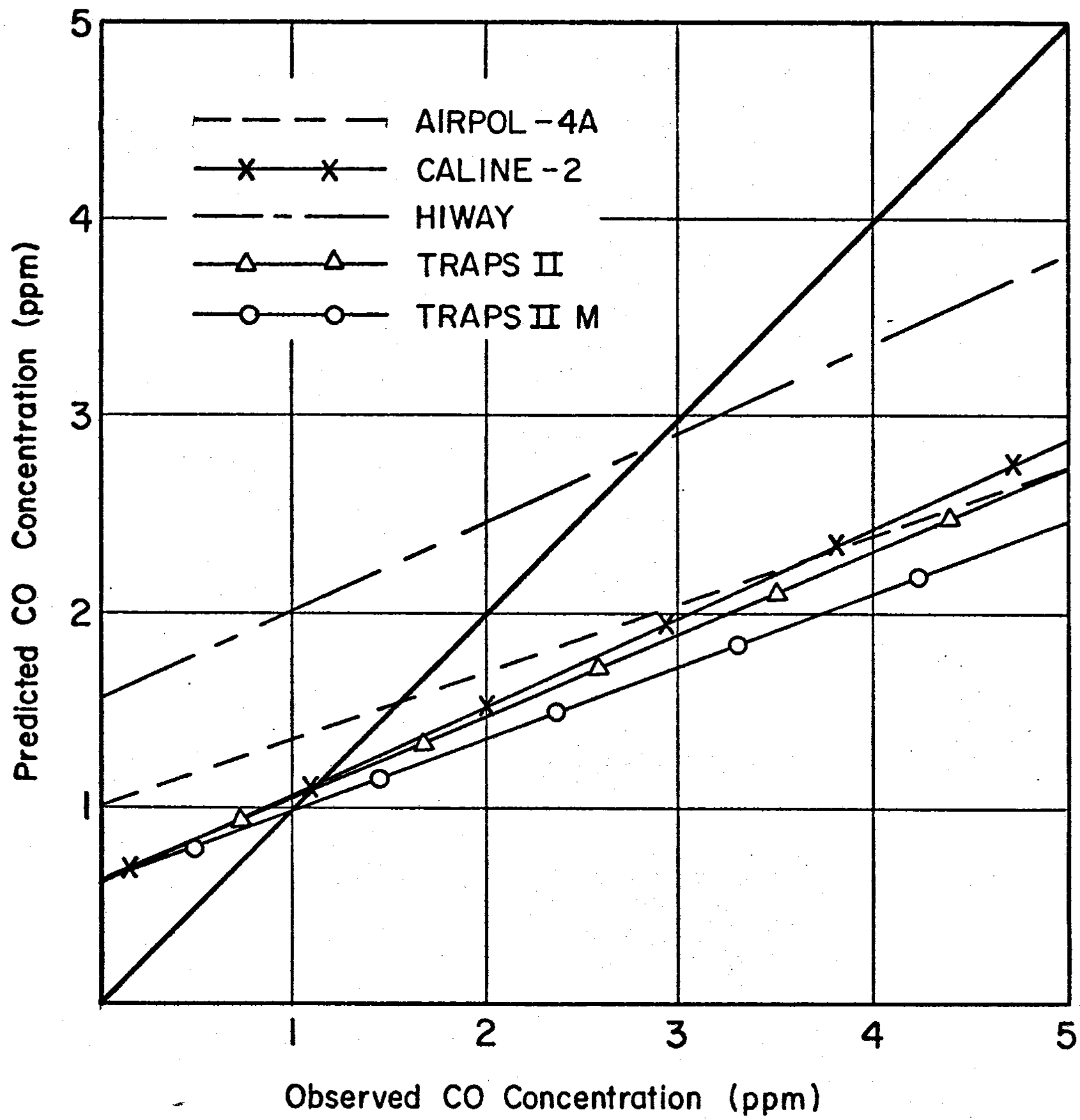

FIGURE 33 Regression Lines of Models for Combined 15-Minute Average Texas Data.

of the slopes are negative. This is because of the low concentration values characteristic of the 15-minute Dallas at-grade data. All concentrations were less than 3.0 ppm. Apparently, the difference in averaging period length had an effect on the average concentration. This is in agreement with theoretical considerations.

The site for which the MOBILE1 and mass balance emission factors have the next best agreement is the San Antonio site. The statistical results for this site are presented in Tables 14, 15, and 23 and Figures 21, 22, and 29. For this site, the intercepts for the regression lines in Figure 22 for the MOBILE1 emission factor are essentially the same as those for the regression lines in Figure 23 for the mass balance emission factor. If Figure 22 is rotated 13^{o} counterclockwise and superimposed on Figure 23, there is very good agreement between the model regression lines. This establishes a relationship between model performances for the two types of emission factors for that site.

Under the assumption that the above relationship holds for the 15-minute cases, the regression lines in Figure 29 may be rotated counterclockwise by approximately the same angle (10^{o}). When this is done, the lines for HIWAY, TRAPS II, and TRAPS IIM coincide very well with the 45^{o} line. This is in support of the assumption about model performance made for the 15-minute cases.

By comparing values of the regression coefficient, it may also be seen that the scatter about the lines are the same for the two different emission factors in the mass balance analysis. Of the three models discussed above, TRAPS IIM has the greatest value for R^2, as well as the smallest probable error, maximum error, and minimum error. The difference in percentage of predictions within ± 1 ppm between the cases for the two different emission factors for the San Antonio site is small, except for AIRPOL-4A. Using this statistic as a performance criterion, all models perform similarly, except for CALINE-2, which is slightly superior, and HIWAY, which is substantially inferior.

Based on the above analysis, it is safe to conclude that TRAPS IIM performs better than the other four models.

Elevated and Cut Sites. Since there are no mass balance cases for the Houston cut and Dallas elevated sites, it is difficult to make model performance comparisons, except for the model predictions based on MOBILE1 emission factors. It is clear, upon examination of Figure 25 for the Houston cut site, that the models all overpredict seriously, especially for low actual concentrations. It is also apparent from the coefficient of determination for the regression lines, that the scatter in the prediction error is very large. The percentage of predictions within $\pm$ 1 ppm is low compared to any of the other sites.

For the Dallas elevated site, the overprediction is not as severe as for the cut site, but the scatter in the prediction error is, again, very large. However, the percent of predicted concentrations within both $\pm$ 1 ppm and $\pm$ 2 ppm are not poor. This indicates low actual concentration values.

Since the performance for all models for these two sites is not satisfactory, no best model is chosen for cut or elevated sites.

Combined Data. The last analysis to be made is that for the combined 15-minute data base. HIWAY may be eliminated from consideration as the best model by virtue of its overprediction for the mass balance emission factor cases. However, the regression lines in Figure 33 for the other models closely resemble the regression lines for the mass balance cases in Figure 25, the graph for the combined site data. If it is again assumed that the transformation between the lines for the MOBILE1 emission factors and the lines for the mass balance emission factors holds true for the 15-minute average cases, one would expect that the regression lines for all of the models, except HIWAY, to approximate the 45^{o} line well for the 15-minute cases. Again, TRAPS IIM produces the largest value for R^2 for the regression, which should be even larger if mass balance type emission factors were to be used.

As stated earlier, an analysis of model results for MOBILE1 emission factors does not seem to be a fair evaluation of model performance. Therefore, the above regression line comparison for the 15-minute average data base should serve as reinforcement of the previous finds for the mass balance data base, and no further speculation will be made using the statistics for the 15-minute average data base.

Computing Requirements. Maldonado (1976) has compared computing time and core requirements for AIRPOL-4A, CALINE-2, HIWAY, and the original TRAPS model. The results of this comparison, as well as the time and core requirements for TRAPS IIM are listed in Table 28. These computing time and core requirements are for a FORTRAN IV Level G compiler on an Amdahl 470/v6 computer, except for TRAPS IIM. The TRAPS IIM model was run on the Amdahl 470/v6 with a WATFIV compiler. This compiler produces an object code which results in larger execution time than for the Level G compiler.

Table 28. Comparative Computing Requirements for Models

Statistic	TRAPS IIM	CALINE-2	HIWAY	AIRPOL-4A	TRAPS
Compile time (seconds)	0.22	1.60	1.43	3.36	1.00
Core (K bytes)	*	104.00	104.00	128.00	92.00
Execution time (seconds)	0.07	0.09	0.48	0.14	0.01
Core (K bytes)	20.00	48.00	44.00	56.00	40.00

TRAPS IIM's execution time per case was 0.07 seconds, which is 22 percent faster than the second fastest model (besides the original TRAPS model), CALINE-2. The core requirement for the object code was 20K bytes, which was less than half of that required by the nearest competitor, HIWAY. The compile time for TRAPS IIM was 0.22 seconds with the WATFIV compiler, as compared to the lowest value for the other models of 1.43 seconds for HIWAY. This may not reflect the real advantage of TRAPS IIM in this respect. The WATFIV compiler is more sophisticated than the Level G compiler, and is therefore probably considerably slower. The output for the TRAPS IIM model runs did not include core requirements for compilation. Therefore, no comparison on this point may be made.

The above comparison clearly indicates that TRAPS IIM has definite computer time and core requirement advantages over AIRPOL-4A, CALINE-2, and HIWAY. As Maldonado pointed out, these advantages are important with respect to implementation of models on minicomputers. TRAPS II has been implemented on a hand held calculator (Bullin and Polasek, 1978b). TRAPS IIM can probably be implemented on a hand held calculator.

Advantages of the present model TRAPS IIM:

The present model, TRAPS IIM, has several advantages over existing models. They are:

(1) Wind speed and diffusivity are variable with height, thereby approximating actual transport characteristics.
(2) Vertical dispersion is enhanced by the proximity of turbulence producing traffic on a roadway.
(3) There is no exclusion of low wind speed cases due to asymptotic limits on model functions.

(4) Diffusion is a function of site topography.

(5) Computer core and execution times are small.

(6) There is no indication of overprediction for parallel wind cases, as there is for other models.

CHAPTER V

SUMMARY OF RESULTS AND CONCLUSIONS

The TRAPS II model for diffusion of carbon monoxide from roadways has been modified. Using the most reliable data available, the road edge concentration profile has been modeled for use in the TRAPS II model.

An extensive data base, extracted from the Texas A&M data base, has been assimilated. This data base is the most detailed and largest single collection of roadway diffusion data to date. Individual records for each concentration value in this data base have been created. These records include all of the independent variables (meteorology, traffic, geometry, etc.), the measured concentration, and the model prediction concentrations for the five models evaluated in this work. These records may be used in future model analysis and performance studies. The GM data base has been assimilated in a fashion similar to that for the Texas A&M data.

The validity of MOBILE1 versus calculated values of emission factors have been investigated. In general, the diffusion models performed much better for emission factors calculated from the actual data than for MOBILE1 emission factors.

The present model was found to predict concentration better for the GM data base than did the other models. This is reflected in the probable error of 0.380 ppb, which is about half of that for the model exhibiting the next smallest value. However, the present model was developed using the GM data. The model also performed best for the Texas data when mass balance emission factors were used. The present model is also faster than the others and requires less than half the core for execution.

The limitations of the model are subjective. The lowest wind speed used was 0.8 miles per hour. The limits for roadway width used were 83 feet and 140 feet. The largest median width for which the model was run was 60 feet.

The present work may be used as the basis for the following studies:

(1) Extension of model applicability to depressed, elevated, and viaduct roadways. This can probably be accomplished most satisfactorily with the use of the Stanford Research Institute data (Dabberdt and Shelar, 1976). This data base became available very late in this work and was therefore not used.

(2) Consideration in the model of low wind speed pluming effects.

(3) Statistical studies using the final data and model predictions records to determine the weak areas of any model.

(4) Determination of finer relationships involved in the dispersion process. This may be accomplished using principle components analysis or factor analysis applied to the GM data base and the flux and concentration profiles drawn in this study.

(5) Implementation of a TRAPS IIM program for hand held calculators.

LITERATURE CITED

Bullin, J. A. and C. Maldonado, "Modeling Carbon Monoxide Dispersion from Roadways," Env. Sci. and Tech. 11(12), 1071, (1977).

Bullin, J. A. and J. C. Polasek, "Analytical and Experimental Assessment of Highway Impact on Air Quality," Texas Transportation Institute, Research Report 218-1, Chemical Engineering Department, Texas A&M University, College Station, Texas (1976).

Bullin, J. A. and J. C. Polasek, "TRAPSII User's Guide: Analytical and Experimental Assessment of Highway Impact on Air Quality," Texas Transportation Institute, Research Report 218-2, Chemical Engineering Department, Texas A&M University, College Station, Texas (1978a).

Bullin, J. A. and J. C. Polasek, "TRAPS 52 User's Guide: Analytical and Experimental Assessment of Highway Impact of Air Quality," Texas Transportation Institute, Research Report 218-3, Chemical Engineering Department, Texas A&M Univeristy, College Station, Texas (1978b).

Bullin, J. A., et al., "Analytical and Experimental Assessment of Highway Impact on Air Quality," Texas Transportation Institute, Research Report 218-4, Chemical Engineering Department, Texas A&M University, College Station, Texas (1979).

Cadle, S. H., et al., "Results of General Motors Sulfate Dispersion Experiment," General Motors Publication GMR-2107, (1976).

Carpenter, W. A. and G. G. Clemena, "AIRPOL-4A An Introduction and User's Guide," Report No. VHTRC 76-R38, Virginia Highway and Transportation Research Council, Charlottsville, Virginia (1976).

Chock, D. P., "General Motors Sulfate Dispersion Experiment: Assessment of the EPA HIWAY Model, "APCA Jour., 27, 39, (1977).

Dabberdt, W. F. and E. Shelar, "Analysis, Experimental Studies, and Evaluation of Control Measures for Air Flows and Air Quality on and Near Highways," Quarterly Progress Report 8 for PHWA Contract DOT-FH-11-8125, Stanford Research Institute (1975).

Green, N. J., et al., "Dispersion of Carbon monoxide from Roadways at Low Wind Speeds," J. Air Poll. Control Soc., 29(10), 1057, (1979).

Green, N. J., "Roadway Pollutant Dispersion: Development of a Data Base and a Model and Evaluation of Five Models," M.S. Thesis, Chemical Engineering Department, Texas A&M University, College Station, Texas (1980).

Jones, K. E. and A. Wilbur, "A User's Manual for the CALINE-2 Computer Program, "Report No. FHWA-RD-76-134, Federal Highway Administration, Washington, D. C., (1976).

Maldonado, C., "Computer Simulation of the Dispersion of Carbon Monixide from Roadways," M.S. Thesis Chemical Engineering Department, Texas A&M University, College Station, Texas (1976).

Moe, R. D., et al., "Effect of Stability Episodes on Air Pollutant Levels Along Roadways," Paper 78-141 presented at National Air Pollution Control Association Meeting, Houston, Texas (June, 1978).

Noll, K. E. et al., "A Comparison of Three Highway Line Source Dispersion Models," Atmospheric Environment, 12, 1323, (1978).

Turner, D. B. "Workbook of Atmospheric Dispersion Estimates," Air Resources Research Office, Environmental Science Services Administration, Public Health Service Publication No. 999-AP-26, Cincinnati, Ohio (1970).

Zimmerman, J. R. and R. S. Thompson, "User's Guide for HIWAY: A Highway Air Pollution Model," National Environmental Research Center, Research Triangle Park, North Carolina (1974).

APPENDIX A

Traffic Estimation for the Dallas Elevated Site

The estimation of traffic data for the northbound lanes at the Dallas elevated site was accomplished by the following routine.

(1) The lanes were numbered exit, 1, 2, 3 on the west (southbound side), from west to east, and 4, 5, 6 on the east (northbound) side, again from west to east. For the present purposes, exit and 1 were considered as the same lane. Loop counter data in the form of 15-minute averages for the period 6/3/77 to 6/28/77 for lanes 2, 3, 4, and 6 were obtained from TDHPT.

(2) Ratios of total daily lane 6 count/total daily lane 3 count and total daily lane 4 count/total daily lane 3 count were calculated for each day during this period, using the loop counter data. Average values of these ratios for each particular weekday (Monday, Tuesday, etc.) were calculated using the individual daily ratios for the respective weekdays.

(3) The total count for lane 3 (measured by radar) for a particular day was obtained from the complete set of 15-minute data cases for that day. The total daily counts for lanes 4 and 6 were then estimated by multiplying the average lane count ratios (obtained from the loop counter data) for that weekday by the total lane 3 radar count.

(4) The loop counter data were available for 24 hour periods, whereas the radar count data were collected for a shorter period during the daylight hours. The total count for lane 6 and lane 4 were extracted from the loop counter data for the actual radar sampling period for the weekday corresponding to the day of interest.

(5) Individual 15-minute count fractions for each lane on each of the loop counter days were calculated by dividing the 15-minute loop count by the total daily count obtained in step 4.

(6) An average value for the 15-minute count fraction was then calculated for each 15-minute period for each day of the week.

(7) The total counts for lanes 6 and 4 estimated in step 3 were then multiplied by the 15-minute count fraction from step 6 for the respective lane, 15-minute period, and weekday of interest. The result was an estimated count for the particular lane for a 15-minute period.

(8) The 15-minute counts for lane 5 were estimated by multiplying the lane 2 count/lane 3 count for that period by the estimated lane 4 count from step 7. The lane 2 and lane 3 count data were available for only one day in the loop data.

APPENDIX B

Location of Type 1 Format 15-minute Data Cases

Table 29. Location of Type 1 Format 15-Minute Average Cases

Tape: ZZ3893 or ZZ3896(*)

Site	File Name	File Number
Houston At-Grade	WYL.NG.WEP.MODA	82
El Paso	WYL.NG.WEP.MODB	86
Dallas At-Grade	WYL.NG.WEP.MOD	81
San Antonio	WYL.NG.WEP.MOD	81
Houston Cut (before traffic editing)	WYL.NG.WEP.CUT15A	55*
Houston Cut (after traffic editing)	WYL.NG.WEP.CUT15B	56*
Dallas Elevated (before traffic editing)	WYL.NG.WEP.ELV15A	65*
Dallas Elevated (after traffic editing)	WYL.NG.WEP.ELV15B	66*

APPENDIX C

Description of Roadway and Receptor Geometry Variables

Table 30. Roadway and Receptor Geometry Data Added to Each Observation in 15-Minute Average Data Base

VARIABLE	DESCRIPTION
WM1	width of main roadway, side 1 (ft.)
WM2	width of main roadway, side 2 (ft.)
WA1	width of access road, side 1 (ft.)
WA2	width of access road, side 2 (ft.)
DA1	distance between main and access roads, side 1 (ft.)
DA2	distance between main and access roads, side 2 (ft.)
DM1M2	distance between side 1 and side 2 of main roadway (ft.)
NLM1	number of lanes on main roadway, side 1
NLM2	number of lanes on main roadway, side 2
NLA1	number of lanes on access road, side 1
NLA2	number of lanes on access road, side 2
ANGLE	roadway angle (^{o} east of north)
EFM1	MOBILE1 emission factor, main roadway, side 1 ($\frac{\text{gmCO}}{\text{veh. mi.}}$)
EFM2	MOBILE1 emission factor, main raodway, side 2 ($\frac{\text{gmCO}}{\text{veh. mi.}}$)
EFA1	MOBILE1 emission factor, access road, side 1 ($\frac{\text{gmCO}}{\text{veh. mi.}}$)
EFA2	MOBILE1 emission factor, access road, side 2 ($\frac{\text{gmCO}}{\text{veh. mi.}}$)
TRFVOLM1	Traffic volume on main roadway, side 1 ($\frac{\text{veh.}}{\text{15-min.}}$)
TRFVOLM2	Traffic volume on main roadway, side 2 ($\frac{\text{veh.}}{\text{15-min.}}$)
TRFVOLA1	Traffic volume on access road, side 1 ($\frac{\text{veh.}}{\text{15-min.}}$)
TRFVOLA2	Traffic volume on access road, side 2 ($\frac{\text{veh.}}{\text{15-min.}}$)

APPENDIX D

Location and Format of Individual 15-Minute Data Case Records

Table 31. Location of Individual 15-Minute Average Records

Tape: ZZ 3896

SITE	DATE	FILE NAME	FILE NO.
Dallas At-Grade	July 20, 1977	MOD.JUL2077.SAS	1
	July 21, 1977	MOD.JUL2177.SAS	2
San Antonio	October 17, 1977	MOD.OCT1777.SAS	3
	October 18, 1977	MOD.OCT1877.SAS	4
	October 7, 1977	MOD.OCT0777.SAS	5
Houston At-Grade	May 26, 1976	MOD.MAY2676.SAS	6
	December 9, 1976	MOD.DEC0976.SAS	7
El Paso	November 29, 1977	MOD.NOV2977.SAS	8
	November 30, 1977	MOD.NOV3077.SAS	9
	December 1, 1977	MOD.DEC0177.SAS	10
	December 3, 1977	MOD.DEC0377.SAS	11
	November 17, 1977	MOD.NOV1777.SAS	12
	November 18, 1977	MOD.NOV1877.SAS	13
	November 16, 1977	MOD.NOV1677.SAS	14
Houston Cut	September 9, 1976	MOD.SEP0976.SAS	15
	September 16, 1976	MOD.SEP1676.SAS	16
	September 21, 1976	MOD.SEP2176.SAS	17
	September 23, 1976	MOD.SEP2376.SAS	18

Table 31. (con'd.)

Tape: ZZ 3896

SITE	DATE	FILE NAME	FILE NO.
Dallas Elevated	May 19, 1977	MOD.MAY1977.SAS	19
	May 26, 1977	MOD.MAY2677.SAS	20
	June 1, 1977	MOD.JUN0177.SAS	21
	June 7, 1977	MOD.JUN0777.SAS	22
	June 8, 1977	MOD.JUN0877.SAS	23
	June 10, 1977	MOD.JUN1077.SAS	24
	June 9, 1977	MOD.JUN0977.SAS	25

Table 32. Format of Records for Files in Table 31

VARIABLE NAME	COLUMNS	VARIABLE NAME	COLUMNS
Name Date	1-20	HA10M	221-230
Interval	21-30	σ	231-240
Time	31-40	WV10M	241-250
VA40M	41-50	σ	251-260
σ	51-60	TMP10M	261-270
HA40M	61-70	σ	271-280
σ	71-80	RH30M	281-290
WV40M	81-90	σ	291-300
σ	91-100	VA1.5M	301-310
TMP30M	101-110	σ	311-320
σ	111-120	HA1.5M	321-330
VA20M	121-130	σ	331-340
σ	131-140	WV1.5M	341-350
HA20M	141-150	σ	351-360
σ	151-160	TMP1.5M	361-370
WV20M	161-170	σ	371-380
σ	171-180	RH1.5M	381-390
TMP20M	181-190	σ	391-400
σ	191-200	PYRAN	401-410
VA10M	201-210	σ	411-420
σ	211-220	CARCOUNT	421-430

Table 32. (cont'd)

VARIABLE NAME	COLUMNS	VARIABLE NAME	COLUMNS
SPEED	431-440	COGL	651-660
CARCOUNTA	441-450	σ	661-670
SPEEDA	451-460	CO6H	671-680
CARCOUNTB	461-470	σ	681-690
SPEEDB	471-480	ZCO	691-700
WM1	481-490	XCO	701-710
WM2	491-500	CO	711-720
WA1	501-510	σ	721-730
WA2	511-520	TRFVOLM1	731-740
DA1	521-530	TRFVOLM2	741-750
DA2	531-540	TRFVOLA1	751-760
DM1M2	541-550	TRFVOLA2	761-770
NLM1	551-560	For Houston Cut Columns	
NLM2	561-570	651-last are as follows:	
NLA1	571-580	COBK	651-660
NLA2	581-590	σ	661-670
ANGLE	591-600	ZCO	671-680
EFM1	601-610	XCO	681-690
EFM2	611-620	CO	691-700
EFA1	621-630	σ	701-710
EFA2	631-640	TRFVOLM1	711-720
STAB	641-650	TRFVOLM2	721-730

Table 32. (cont'd)

VARIABLE NAME	COLUMNS
TRFVOLA1	731-740
TRFVOLA2	741-750

Variables in Table 32 are as described previously. The new variables are as follows:

STAB - Turner stability class (1,2,3,4,5,6)

XCO - Distance of CO observation from main roadway (ft.)

ZCO - Height of CO observation (ft.)

CO - CO concentration at (XCO, ZCO) (ppm)

There is one aspect of the data that is worthy of note. For the San Antonio and Dallas at-grade sites, the values of TRFVOLM1, TRFVOLM2, TRFVOLA1, and TRFVOLA2 are not correct on the files listed in this appendix. These values are correct in the final data base used for model evaluation. The format and location of the correct data are given in Tables 33 and 34.

Table 33. Files Containing Traffic Data for Dallas At-Grade Site

FILE NAME	FILE NO.	TAPE
WYL.NG.WCG.DAGTRAF	57	ZZ3893

FORMAT

VARIABLE	COLUMNS	FORMAT
Date	1-7	A7
Time	10-13	A4
VOLM1	16-18	I3
VOLM2	20-22	I3
VOLA1	24-25	I2
VOLA2	27-28	I2

Table 34. Files Containing Traffic Data for the San Antonio Site

FILE NAME	FILE NUMBER	TAPE
EP.TRFVOL.OCT0777	228	ZZ3893
EP.TRFVOL.OCT1777	229	ZZ3893
EP.TRFVOL.OCT1877	230	ZZ3893

FORMAT

VARIABLE	COLUMNS	FORMAT
TRFVOLA1	1-5	I5
TRFVOLM1	11-15	I5
TRFVOLM2	16-20	I5

APPENDIX E

Location and Variable Descriptions

for the GM Data Base

Table 35. GM Data Base Variables

SAS name GM MODELS on Tape ZZ3893

File Name: WYL.NG.WC6.GMMODS1

VARIABLE NAME	DESCRIPTION	NOTES
PERIOD	10-digit identifies first four - day of year next two - hour after midnight next two - minute of hour next two - second of minute	SAS Character 10 format
RI	Richardson number from GMR-2107	
CHAN	Data channel corresponding to a particular location at sampling site from GMR-2107	
VERW	Vertical wind speed at a particular location; from GMR-2107	units are cm/sec
WSPO	Horizontal wind speed at a particular location; from GMR-2107	units are cm/sec
WDIR	Wind direction at a particular location; wrt north; 0-360 clockwise from GMR-2107	units are degrees
TEMP	Temperature at a given location; from GMR-2107	units are ^{o}K
SF_6	Sulfur hexafluoride concentration at a particular location; from GMR-2107	units are ppb
CALTEMP	Temperature at 1.5 m level on 30 m upwind tower; from GMR-2107	units are ^{o}K
PRESS	Pressure during sampling period; from GMR-2107	units are mm Hg
TOWER	Tower number, 1-8 west to east	
H	Normal height on tower	units are m
UX	Wind speed normal to roadway	units are cm/sec

Table 35. (cont'd)

VARIABLE NAME	DESCRIPTION	NOTES
NORMSF6	SF6 concentration normalized to flow rate of 3.5 ℓ/min, temp. of 298.15 ^{o}K, pressure of 760 mm Hg	units are ppb
STAB	Turnur stability classification, from Chock (1977)	
LPRIMINV	Inverse Monin-Obukhov length X10, from Chock (1977)	
USTAR	Friction velocity, calculated from 1.5 m level wind speed at 50 m upwind tower	units are cm/sec
ACUTHETA	Acute angle of wind with respect to traffic in upwind lane; + is with traffic flow; - is opposed to traffic flow	units are degrees
DIRECT	Class variable for wind orientation wrt roadway values are either 'NOTPAR__' or 'PARALLEL'	SAS character 8 format
SPEED	Class variable for wind speed; values are 'HIWIND' or 'LOWIND'	SAS character 6 format
WIND	Class variable for side of road from which wind is blowing; values are 'EASTWIND' or 'WESTWIND'	SAS character 8 format
AIRPOL	AIRPOL-4A predicted SF6 concentration at given location	units are ppb
CALINE	CALINE-2 predicted SF6 conc. at given location	units are ppb
HIWAY	HIWAY predicted SF6 conc. at given location	units are ppb
TRAPS	TRAPS II predicted SF6 conc. at given location	units are ppb
TRAPS IIM	TRAPS IIM predicted SF6 conc. at given location	units are ppb

All missing values are entered as a single decimal point (.).

APPENDIX F

Conversion of Road Edge SF_6 Concentration Model to CO Basis

The road edge SF_6 concentration model may be converted to a model for prediction of CO concentrations. The conversion is accomplished by the following routine.

Let Q'_n be the line source strength for the GM data base at a tracer flowrate of 3.5 ℓ/min. Q'_n is expressed in units of /mi hr. and is calculated by

$$Q'_n = \frac{3.5\ \ell}{min} \times \frac{2}{10\ km} \times \frac{1.609\ km}{mi} \times \frac{60\ min}{hr} \qquad \text{(F-1)}$$

$$= 67.578\ \frac{\ell}{mi\ hr}$$

The line source strength for carbon monoxide emitted by automobiles on a roadway is given by

$$Q' = \frac{EF\ gm}{veh\ mi} \times \frac{VOL\ veh}{hr} \times \frac{0.08250\ \ell\ atm}{gmol\ K} \times \frac{gmol}{28\ gm} \times \frac{1}{atm} \qquad \text{(F-2)}$$

$$\times \frac{(T\ ^oF + 460)\ \ ^oR}{1.8\ ^oR/K}$$

$$= EF \times VOL \times (T + 460) \times 0.001628\ \ \ell/mi\ hr$$

where EF = automobile CO emission factor (gm/veh mi)

VOL = traffic volume on the roadway (veh/hr)

T = temperature at the roadway (^oF)

Concentration of carbon monoxide is calculated by

$$CO(ppb) = \frac{Q'}{Q'_n} \times SF6STD(ppb) \qquad \text{(F-3)}$$

$$= \frac{0.001628}{67.578} \times EF \times VOL \times (T + 460) \times SF6STD$$

$$= 2.409 \times 10^{-5} \times EF \times VOL \times SF6STD \times (T + 460)$$

where SF6STD is the SF_6 concentration calculated by the third order road edge model. Since 1 ppm is equal to 10^3 ppb

$$CO(ppm) = 2.409 \times 10^{-8} \times EF \times VOL \times (T + 460) \times SF6STD \qquad \text{(F-4)}$$

For a temperature of 80° F

$$CO(ppm) = 1.301 \times 10^{-5} \times EF \times VOL \times SF6STD \qquad (F-5)$$

If the assumption that the road edge concentration is inversely proportional to roadway width is made, then the model becomes

$$CO(ppm) = 1.301 \times 10^{-5} \times 31.39 \times \frac{SF6STD \times EF \times VOL}{W} \qquad (F-6)$$

where 31.39 = width of the GM roadway (m)

W = general roadway width (m)

APPENDIX G

TRAPS IIM Source Listing

```
      DIMENSION XDIST(6).ZDIST(6)
      COMMON HEADER(20).NPAGE.NFLAG.MN.DY.YR
      COMMON /AREA3/VEL(2).DIFFY.JBORT.ERFUN
      COMMON /AREA1/HEIGHT(4).USTAR
      COMMON /AREA2/VPH.EFACT.NRP.STAB.THETA
      COMMON /AREA4/PPM(6,6).CO(4),R.VAR1.VAR2.XPRIME
      REAL  RFMT1(7)/'(','    ','F5.0','.5X,','    ','F5.0',')'/
      REAL   DIGIT(6)/'1','2','3','4','5','6'/
      INTEGER RDR/5/.PCOUNT/0/
      NFLAG=0
      NPAGE=0
   10 READ (5,500.END=900) (HEADER(I).I=1,15)
      READ (5,501) VPH.EFACT.UBAR.THETA.STAB.HWID
      READ (5,502) XDIST.ZDIST
      RUFHT=2.62
      NRP=6
      REFHT=26.
  500 FORMAT (15A4)
  501 FORMAT (F10.0,3(F5.0),5X,2(F5.0))
  502 FORMAT (6F5.0.5X.6F5.0)
      CALL TRAPS2 (HWID.REFHT.RUFHT.UBAR.NRP.NRP.XDIST.ZDIST)
   50 PCOUNT=PCOUNT+1
      NX=PCOUNT/2
      IF(FLOAT(PCOUNT)/2.0-NX .GT. 0.0) GO TO 55
      NFLAG=0
      GO TO 60
   55 NFLAG=1
   60 CALL OUTPUT (XDIST.ZDIST.REFHT.RUFHT.UBAR.HWID)
      GO TO 10
  900 RETURN
      END
      SUBROUTINE OUTPUT (XDIST.ZDIST.REFHT.RUFHT.UBAR.HWID)
      DIMENSION XDIST(6).ZDIST(6)
      COMMON HEADER(20).NPAGE.NFLAG.MN.DY.YR
```

```
      COMMON /AREA3/VEL(2),DIFFY,JABORT,ERFUN                           TRAPS035
      COMMON /AREA1/HEIGHT(4),USTAR                                     TRAPS036
      COMMON /AREA2/VPH,EFACT,NRP,STAB,THETA                            TRAPS037
      COMMON /AREA4/PPM(6,6),CO(4),R,VAR1,VAR2,XPRIME                   TRAPS038
      INTEGER PTR/6/,TRACE/1/                                           TRAPS039
      IF(NFLAG.NE.1) GO TO 20                                           TRAPS040
      NPAGE=NPAGE+1                                                     TRAPS041
      WRITE(PTR,600) NPAGE,MN,DY,YR                                     TRAPS042
   20 IF(TRACE.EQ.0) WRITE(PTR,605)                                     TRAPS043
      WRITE(PTR,601) (HEADER(I),I=1,15),VPH,EFACT,REFHT,RUFHT,UBAR,HWID TRAPS044
      IF(JABORT.LT.1) GO TO 40                                          TRAPS045
      WRITE(PTR,602) JABORT                                             TRAPS046
      RETURN                                                            TRAPS047
   40 IF(TRACE-1) 70,60,50                                              TRAPS048
   50 ABORT=6                                                           TRAPS049
      WRITE(PTR,602) JABORT                                             TRAPS050
      GO TO 80                                                          TRAPS051
   60 WRITE(PTR,604) USTAR,VEL(1),VEL(2),DIFFY,XPRIME                   TRAPS052
      GO TO 80                                                          TRAPS053
   70 WRITE(PTR,610)                                                    TRAPS054
   80 WRITE(PTR,606)                                                    TRAPS055
      WRITE(PTR,607)                                                    TRAPS056
      WRITE(PTR,608) (XDIST(I),I=1,NRP)                                 TRAPS057
      JP=NRP+1                                                          TRAPS058
      DO 90 JX=1,NRP                                                    TRAPS059
   90 WRITE(PTR,609) ZDIST(JP-JX),(PPM(KK,JP-JX),KK=1,NRP)              TRAPS060
  600 FORMAT(1H1,T3,72HTEXAS A&M UNIVERSITY, CHEMICAL ENGINEERING DEPT.,TRAPS061
     > COLLEGE STATION, TEXAS,T78,5HPAGE ,I3/T2,17HAIR QUALITY MODEL,T35TRAPS062
     >,A3,A3,A2,T60,13H*** TRAPS ***)                                   TRAPS063
  601 FORMAT(1H0,T21,40HMICROSCALE DISPERSION OF CARBON MONOXIDE//15A4//TRAPS064
     >T28,18HVEHICLES PER HOUR=,F6.0/T30,16HEMISSION FACTOR=,F6.0,T54,  TRAPS065
     >6HGMS/MI/T29,17HREFERENCE HEIGHT=,F6.2,T54,4HFEET/T29,17HROUGHNESSTRAPS066
     > HEIGHT=,F6.2,T54,4HFEET/T31,15HMEAN WIND VEL.=,F6.2,T54,8HMILES/HTRAPS067
     >R/T32,14HHIGHWAY WIDTH=,F6.2,T54,4HFEET)                          TRAPS068
  602 FORMAT(1H-,T36,13HABORT CODE 00,I1,2H <,20(1H-),8H N O T E,15(/)) TRAPS069
```

```
  604 FORMAT(1H ,T28,18HFRICTION VELOCITY=,F6.2,T54,8HMILES/HR/T23,23HWITRAPS070
     >ND VELOCITY AT ONE M=,F6.2,T54,8HMILES/HR/T23,23HWIND VELOCITY AT TRAPS071
     >TEN M=,F6.2,T54,8HMILES/HR/T29,17HEDDY DIFFUSIVITY=,F6.2,T54,13HMETRAPS072
     >TERS**2/SEC/T31,15HVIRTUAL ORIGIN=,F6.1,T54,4HFEET)              TRAPS073
  605 FORMAT(1H0)                                                       TRAPS074
  606 FORMAT(1H ,/T26,32HPREDICTED CO CONCENTRATION (PPM),/)            TRAPS075
  607 FORMAT(1H ,T15,8HRECEPTOR,T33,22HDISTANCE PERPENDICULAR,/T16,6HHEITRAPS076
     >GHT,T34,20HTO HIGHWAY  (X FEET),/T15,8H(Z FEET))                  TRAPS077
  608 FORMAT(1H+,T23,6F7.1,/)                                           TRAPS078
  609 FORMAT(1H ,T15,F5.1,T23,6F7.2)                                    TRAPS079
  610 FORMAT(1H-)                                                       TRAPS080
      RETURN                                                            TRAPS081
      END                                                               TRAPS082
      SUBROUTINE TRAPS2 (XHWID,XREFH,XRUFH,XUBAR,NX,NZ,X,Z)             TRAPS083
C                                                                       TRAPS084
C                                                                       TRAPS085
C                                                                       TRAPS086
C                                                                       TRAPS087
C.......................................................................TRAPS088
C       INTRODUCTION.                                                   TRAPS089
C.......................................................................TRAPS090
C     TRAPS2 IS A SUBROUTINE VERSION OF THE TRAPS ROADWAY AIR POLLUTION TRAPS091
C     PROGRAM DEVELOPED AT TEXAS A & M UNIVERSITY'S CHEMICAL ENGINEERING TRAPS092
C     DEPARTMENT BY CESAR MALDONADO AND DR. J. A. BULLIN IN 1975.  THE  TRAPS093
C     ORIGINAL TRAPS MODEL RELIED HEAVILY ON WORK DONE BY O. G. SUTTON, TRAPS094
C     D. B. TURNER, AND F. PASQUILL.  SOME MODIFICATIONS TO THE MODEL   TRAPS095
C     BY JOHN POLASEK AND DR. J. A. BULLIN RESULTED IN A FASTER,        TRAPS096
C     SMALLER VERSION NAMED TRAPS II.  FURTHER MODIFICATIONS BY         TRAPS097
C     NICHOLAS J. GREEN AND DR. J. A. BULLIN IN 1979, BASED ON THE      TRAPS098
C     GENERAL MOTORS SULFATE DISPERSION EXPERIMENT DATA, RESULTED IN    TRAPS099
C     THE PRESENT VERSION.                                              TRAPS100
C                                                                       TRAPS101
C                                                                       TRAPS102
C     ALL DEVELOPMENTAL WORK FOR THE PREVIOUS SUBROUTINE WAS CARRIED    TRAPS103
C     OUT ON AN AMDAHL 470 V/6 COMPUTER, AND CROSS CHECKED ON A         TRAPS104
```

```
C    META-4 COMPUTER TO TEST MULTI MACHINE COMPATIBILITY.  THE             TRAPS105
C    DEVELOPEMENTAL WORK FOR THE PRESENT VERSION WAS CARRIED OUT           TRAPS106
C    ON THE AMDAHL MACHINE ONLY.                                           TRAPS107
C.......................................................................TRAPS108
C                                                                          TRAPS109
C                                                                          TRAPS110
C                                                                          TRAPS111
C                                                                          TRAPS112
C.......................................................................TRAPS113
C      DESCRIPTION OF VARIABLES.                                           TRAPS114
C.......................................................................TRAPS115
C   VARIABLE VARIABLE  PRIMARY    SECONDARY        VARIABLE                TRAPS116
C       #       NAME     UNITS       UNITS       DESCRIPTION               TRAPS117
C=======================================================================TRAPS118
C       1      XHWID     FEET       METERS     ROADWAY WIDTH.              TRAPS119
C-----------------------------------------------------------------------TRAPS120
C       2      XREFH     FEET       METERS     HEIGHT OF WINDSPEED         TRAPS121
C                                              MEASUREMENTS.               TRAPS122
C-----------------------------------------------------------------------TRAPS123
C       3      XRUFH     FEET       METERS     ROUGHNESS HEIGHT.           TRAPS124
C-----------------------------------------------------------------------TRAPS125
C       4      XUBAR     MILE/HOUR METER/SEC  WIND SPEED AT XREFHT.        TRAPS126
C-----------------------------------------------------------------------TRAPS127
C       5      VPH       VEHICLES PER HOUR     VEHICLES PER HOUR.          TRAPS128
C-----------------------------------------------------------------------TRAPS129
C       6      EFACT     GRAM/VEHICLE-MILE     EMISSION FACTOR.            TRAPS130
C-----------------------------------------------------------------------TRAPS131
C       7      NX        *****      *****      # OF DOWNWIND RECEPTOR      TRAPS132
C                                              DISTANCES.                  TRAPS133
C-----------------------------------------------------------------------TRAPS134
C       8      NZ        *****      *****      # OF RECEPTOR HEIGHTS.      TRAPS135
C-----------------------------------------------------------------------TRAPS136
C       9      X         FEET       METERS     VECTOR OF DOWNWIND          TRAPS137
C                                              RECEPTOR DISTANCES.         TRAPS138
C-----------------------------------------------------------------------TRAPS139
```

```
      DIFFY=0.0
      ALPHA=0.0
      COH=0.0
      XPRIM=0.0
C.....................................................................
C
C
C
C
C.....................................................................
C      CONVERT INPUT PARAMETERS AS NECESSARY TO GET TO METRIC UNITS.
C.....................................................................
      JBORT=2
      HWID=-XHWID
      IF (HWID) 10,240,20
   10 HWID=XHWID*0.3048
   20 HWID=HWID+6.096
      REFHT=-XREFH
      IF (REFHT)30,40,40
   30 REFHT=XREFH*0.3048
   40 RUFHT=-XRUFH
      IF (RUFHT) 50,60,60
   50 RUFHT=XRUFH*0.3048
   60 UBAR=-XUBAR
      IF (UBAR) 70,80,80
   70 UBAR=XUBAR*0.44704
   80 CONTINUE
      DO 100 I=1,NX
      XDIST(I)=-X(I)
      IF (XDIST(I)) 90,100,100
   90 XDIST(I)=X(I)*.3048
  100 XDIST(I)=XDIST(I)-3.048
      JBORT=1
      DO 140 I=1,NZ
      ZDIST(I)=-Z(I)
```

```
      IF (ZDIST(I)) 110,240,120                                         TRAPS210
  110 ZDIST(I)=Z(I)*0.3048                                              TRAPS211
  120 CONTINUE                                                          TRAPS212
      IF (ZDIST(I)-1.) 130,130,140                                      TRAPS213
  130 JBORT=-1                                                          TRAPS214
  140 CONTINUE                                                          TRAPS215
C.......................................................................TRAPS216
C                                                                       TRAPS217
C                                                                       TRAPS218
C                                                                       TRAPS219
C                                                                       TRAPS220
C.......................................................................TRAPS221
C       CHECK INPUT PARAMETERS FOR VALIDITY.                            TRAPS222
C.......................................................................TRAPS223
      IF (HWID-15.) 150,160,160                                         TRAPS224
  150 JBORT=-2                                                          TRAPS225
  160 CONTINUE                                                          TRAPS226
      IF (RUFHT-0.01) 180,170,170                                       TRAPS227
  170 CONTINUE                                                          TRAPS228
      IF (RUFHT-0.8) 190,180,180                                        TRAPS229
  180 JBORT=3                                                           TRAPS230
  190 CONTINUE                                                          TRAPS231
      IF (REFHT-RUFHT) 200,200,210                                      TRAPS232
  200 JBORT=4                                                           TRAPS233
  210 CONTINUE                                                          TRAPS234
      IF ( JBORT - 1 ) 220,220,240                                      TRAPS235
C.......................................................................TRAPS236
C                                                                       TRAPS237
C                                                                       TRAPS238
C                                                                       TRAPS239
C                                                                       TRAPS240
C.......................................................................TRAPS241
C       GENERATE METEROLOGICAL PARAMETERS.                              TRAPS242
C.......................................................................TRAPS243
  220 CONTINUE                                                          TRAPS244
```

```
      USTAR=UBAR*0.4/ALOG(REFHT/RUFHT)
      DIFFY=0.8*USTAR
      VEL(1)=(USTAR/0.4)*ALOG(1.0/RUFHT)
      VEL(2)=(USTAR/0.4)*ALOG(10.0/RUFHT)
      IF (VEL(2)-0.000) 230,260,260
C.....................................................................
C
C
C
C
C.....................................................................
C        FATAL ERROR HANDLER.
C.....................................................................
  230 JBORT=5
  240 CONTINUE
      JBORT=IABS(JBORT)
      DO 250 I=1,NX
      DO 250 J=1,NZ
      PPM(I,J)=-1000000.
  250 CONTINUE
      GO TO 380
C.....................................................................
C
C
C
C
C.....................................................................
C        CALCULATE THE ROADEDGE CONCENTRATION.
C.....................................................................
  260 IF (RUFHT.GE.0.1) GO TO 261
      ALPHA=0.122582+4.093518*RUFHT-59.46828*RUFHT**2+550.0142*RUFHT**3-
     >1965.479*RUFHT**4
      GO TO 262
  261 ALPHA=((3.426858*RUFHT-3.828798)*RUFHT+2.03853)*RUFHT+.11283
  262 CALL ORIGIN (ALPHA)
```

```
      IF (JBORT.EQ.6) GO TO 240
C...........................................................................
C
C
C
C
C...........................................................................
C       CALCULATE THE CONCENTRATIONS AT THE DOWNWIND RECEPTORS.
C...........................................................................
  300 CONTINUE
      JBORT=JBORT-1
      DO 360 IZ=1,NX
      XDIST(IZ)=XDIST(IZ)+XPRIM
      IF ( XDIST(IZ) - XPRIM ) 310,310,320
  310 XDIST(IZ)=XPRIM
  320 CONTINUE
      DO 360 IP=1,NZ
       EXPRG=ZDIST(IP)**R*VAR2/XDIST(IZ)
      IF ( EXPRG - 150.) 330,330,350
  330 PPM(IZ,IP)=VAR1*VAR2*875./(XDIST(IZ)*2.7183**EXPRG)
      IF ( JBORT ) 340,360,240
  340 PPM(IZ,IP)=-PPM(IZ,IP)
      GO TO 360
  350 PPM(IZ,IP)=0.0
  360 CONTINUE
C...........................................................................
C
C
C
C
C
C...........................................................................
C       CONVERT SCRATCH PARAMETERS TO ENGLISH UNITS.
C...........................................................................
      IF (JBORT) 370,380,380
```

```
  370 JBORT=JBORT+1
  380 CONTINUE
      USTAR=USTAR/0.44704
      VEL(1)=VEL(1)/0.44704
      VEL(2)=VEL(2)/0.44704
      XPRIM = XPRIM/0.3048-10.
C......................................................................
C
C
C
C
C......................................................................
C      RETURN TO MAIN
C......................................................................
      RETURN
      END
C......................................................................
C
C
C
C
C......................................................................
      SUBROUTINE ORIGIN(ALPHA)
C
C......................................................................
C      SUBROUTINE ORIGIN SOLVES FOR A VIRTUAL ORIGIN DISTANCE
C      USING EMPERICALLY DERIVED EQUATIONS
C......................................................................
C
      COMMON /AREA1/HEIGHT(4),USTAR
      COMMON /AREA2/VPH,EFACT,NRP,STAB,THETA
      COMMON /AREA3/VEL(2),DIFFY,JBORT,ERFUN
      COMMON /AREA4/PPM(6,6),CO(4),R,VAR1,VAR2,XPRIM
      COMMON /AREA5/HWID,REFHT,RUFHT,UBAR,XDIST(6),ZDIST(6)
      REAL LL
```

```
      EXTERNAL GPPM                                                     TRAPS350
      HEIGHT(3)=9.4488                                                  TRAPS351
      HEIGHT(2)=3.353                                                   TRAPS352
      HEIGHT(1)=0.6096                                                  TRAPS353
      THETB=THETA*0.01745329                                            TRAPS354
      UX=UBAR*SIN(THETB)*100.0                                          TRAPS355
      A0EGE=2.618-0.007577*UX+0.009917*THETA+0.1284*STAB                TRAPS356
      A1EGE=0.9923-1.303*A0EGE+0.3788*A0EGE**2-0.03946*A0EGE**3         TRAPS357
      A2EGE=-0.02118-0.1136*A1EGE                                       TRAPS358
      A3EGE=0.00027169-0.03160438*A2EGE                                 TRAPS359
      DO 10 I=1,3                                                       TRAPS360
      X=A0EGE+A1EGE*HEIGHT(I)+A2EGE*HEIGHT(I)**2.0+A3EGE*HEIGHT(I)**3.0 TRAPS361
      IF (X.LT.0.) X=1.E-15                                             TRAPS362
      QPRIM=VPH*EFACT                                                   TRAPS363
      COPPM=X*QPRIM*4.083956E-04/HWID                                   TRAPS364
   10 CO(I)=COPPM/875                                                   TRAPS365
      R=ALPHA+1.0                                                       TRAPS366
      VAR1=VPH*EFACT*1.73E-07*R/VEL(1)                                  TRAPS367
      VAR2=VEL(1)/(R*R*DIFFY)                                           TRAPS368
      CALL PWRFIT (0.3,0.31,1.0,1.E-03,2.E-06,30,XPRIM,GPPM)            TRAPS369
      RETURN                                                            TRAPS370
      END                                                               TRAPS371
C.......................................................................TRAPS372
C                                                                       TRAPS373
      SUBROUTINE PWRFIT(LL,UL,DELTA,EPS1,EPS2,MAXIT,XROOT,F)            TRAPS374
C                                                                       TRAPS375
C.......................................................................TRAPS376
C       SUBROUTINE PWRFIT IS USED IN FINDING A VALUE FOR THE VIRTUAL    TRAPS377
C       ORIGIN DISTANCE. THIS SUBROUTINE CALLS SUBROUTINE MRF, WHICH    TRAPS378
C       IS A MODIFIED REGULA FALSI ROUTINE USED TO FIND THE ROOT OF     TRAPS379
C       A SPECIFIED FUNCTION, GPPM.                                     TRAPS380
C.......................................................................TRAPS381
C                                                                       TRAPS382
      COMMON /AREA3/VEL(2),DIFFY,JBORT,ERFUN                            TRAPS383
      EXTERNAL F                                                        TRAPS384
```

```
      REAL LL                                                           TRAPS385
      ICNT=0                                                            TRAPS386
      INDEX=0                                                           TRAPS387
      XROOT=-99.9                                                       TRAPS388
      STORE1=LL                                                         TRAPS389
      STORE2=UL                                                         TRAPS390
      STORE3=DELTA                                                      TRAPS391
    6 IX=0                                                              TRAPS392
      ICNT=ICNT+1                                                       TRAPS393
    7 CALL MRF(LL,UL,EPS1,EPS2,MAXIT,KFLAG,F)                           TRAPS394
      IF (KFLAG.LT.3) GO TO 10                                          TRAPS395
      JBORT=6                                                           TRAPS396
      IX=IX+1                                                           TRAPS397
      LT=100                                                            TRAPS398
      IF (LL.GT.152) GO TO 15                                           TRAPS399
      IF (IX.LE.LT) GO TO 8                                             TRAPS400
   15 IF (XROOT.NE.-99.9) GO TO 12                                      TRAPS401
      LL=STORE1                                                         TRAPS402
      UL=STORE2                                                         TRAPS403
      DELTA=STORE3                                                      TRAPS404
      RETURN                                                            TRAPS405
    8 LL=UL                                                             TRAPS406
      UL=UL+DELTA                                                       TRAPS407
      GO TO 7                                                           TRAPS408
   10 XROOT=(LL+UL)/2.0                                                 TRAPS409
      IF (ICNT.NE.1) GO TO 11                                           TRAPS410
      IF (INDEX.EQ.1) GO TO 13                                          TRAPS411
      DELTA=0.2                                                         TRAPS412
      UL=LL+0.2                                                         TRAPS413
      INDEX=1                                                           TRAPS414
      SAVRT=XROOT                                                       TRAPS415
      GO TO 7                                                           TRAPS416
   13 SAVRT=XROOT                                                       TRAPS417
      ERROR=ERFUN                                                       TRAPS418
   14 LL=XROOT+0.1                                                      TRAPS419
```

```
      UL=XROOT+0.11                                                     TRAPS420
      DELTA=10.0                                                        TRAPS421
      IF (LL.LT.152.) GO TO 6                                           TRAPS422
      GO TO 12                                                          TRAPS423
   11 IF (ERFUN.LT.ERROR) GO TO 13                                      TRAPS424
      GO TO 14                                                          TRAPS425
   12 LL=STORE1                                                         TRAPS426
      UL=STORE2                                                         TRAPS427
      DELTA=STORE3                                                      TRAPS428
      XROOT=SAVRT                                                       TRAPS429
      JBORT=1                                                           TRAPS430
      RETURN                                                            TRAPS431
      END                                                               TRAPS432
C.......................................................................TRAPS433
C                                                                       TRAPS434
C                                                                       TRAPS435
C                                                                       TRAPS436
C                                                                       TRAPS437
C.......................................................................TRAPS438
      SUBROUTINE MRF(LL,UL,EPS1,EPS2,MAXIT,KFLAG,F)                     TRAPS439
C                                                                       TRAPS440
C.......................................................................TRAPS441
C       THIS SUBROUTINE IS A MODIFIED REGULA FALSI ROUTINE              TRAPS442
C.......................................................................TRAPS443
C                                                                       TRAPS444
      REAL LL                                                           TRAPS445
      KFLAG=0                                                           TRAPS446
      FLL=F(LL)                                                         TRAPS447
      FUL=F(UL)                                                         TRAPS448
      SNFLL=SIGN(1.,FLL)                                                TRAPS449
      IF (SNFLL*FUL.LE.0.) GO TO 13                                     TRAPS450
      KFLAG=3                                                           TRAPS451
      RETURN                                                            TRAPS452
   13 XL=LL                                                             TRAPS453
      FXL=FLL                                                           TRAPS454
```

```
      DO 17 J=1,MAXIT
      IF (ABS(UL-LL/2.).LE.EPS1) RETURN
      IF (ABS(FXL).GT.EPS2) GO TO 15
      LL=XL
      UL=XL
      KFLAG=1
      RETURN
   15 XL=(FLL*UL-FUL*LL)/(FLL-FUL)
      SNFXL=SIGN(1.,FXL)
      FXL=F(XL)
      NJ=J-1
      IF (SNFLL*FXL.LT.0.) GO TO 16
      LL=XL
      FLL=FXL
      IF (FXL*SNFXL.GT.0.) FUL=FUL/2.
      GO TO 17
   16 UL=XL
      FUL=FXL
      IF (FXL*SNFXL.GT.0.) FLL=FLL/2.
   17 CONTINUE
      KFLAG=2
      RETURN
      END
C.......................................................................
C
C
C
C
C.......................................................................
      FUNCTION GPPM(X)
C
C.......................................................................
C       THIS FUNCTION IS THE MINIMIZATION FUNCTION FOR THE
C       VIRTUAL ORIGIN DISTANCE
C.......................................................................
```

```
C
      COMMON /AREA1/HEIGHT(4),USTAR
      COMMON /AREA3/VEL(2),DIFFY,JBORT,ERFUN
      COMMON /AREA4/PPM(6,6),CO(4),R,VAR1,VAR2,XPRIM
      SUM=0.0
      ERFUN=0.0
      DO 17 J=1,3
      EXPRG=HEIGHT(J)**R*VAR2/X
      IF (EXPRG.GE.150) GO TO 7
      CHI=VAR1*VAR2*EXP(-EXPRG)/X
      GO TO 8
    7 CHI=0.0
    8 CARB=CO(J)
      DIF=(CHI-CARB)**2
      FMIN=(CHI-CARB)*(CHI/X**2)*((VEL(1)*HEIGHT(J)**R)/(DIFFY*R*R)-X)
      ERFUN=ERFUN+DIF
   17 SUM=SUM+FMIN
      GPPM=2*SUM
      RETURN
      END
```

APPENDIX H

Conversion of MOBILE1 Emission Factor to HIWAY Emission Rate

The MOBILE1 emission factor may be converted to the emission rate required as input by HIWAY by the following equation:

$$ER_H \left(\frac{gm}{sec\ m}\right) = EF_{M1} \left(\frac{gm}{veh\ mi}\right) \times TRAF \left(\frac{veh}{hr}\right) \times \frac{1}{3600}\left(\frac{hr}{sec}\right) \times \frac{1}{1609}\left(\frac{mi}{m}\right) \qquad (H-1)$$

where ER_H - emission rate required for HIWAY

EF_{M1} = emission factor returned by MOBILE1

TRAF = traffic rate on lane of interest

Since traffic data (speed, volume) are available for each lane, it is possible to calculate a MOBILE1 emission factor for each lane and convert it to the HIWAY emission rate. This was done for all cases except those for Houston cut and Dallas elevated sites and the GM cases. For these cases the following routine was used. For each lane group for which HIWAY predictions were sought, one emission rate calculated with the traffic volume and average speed for that lane group was calculated. This value was divided by the number of lanes in that lane group and entered as the emission rate for each lane. Therefore, for a roadway with n lanes, there are n equal emission rate values supplied to HIWAY.

The input information for MOBILE1 was in error at the time the pollution models were run. This was discovered after the results were tabulated for all sites except Houston cut and Dallas elevated. The same error was made for the mass balance cases and was also discovered. MOBILE1 was rerun for those cases and the correct emission factors used for the analysis of those cases. However, since there were many 15-minute averaging periods, a solution other than rerunning the models for each case was used.

Using the erroneous and correct MOBILE1 emission factors, the average value of the ratio of the correct emission factor divided by the erroneous emission factor was calculated for each site represented in the mass balance cases. Since the concentration of pollutant is directly proportional to the emission factor, the results of the models were multiplied by the ratios above to obtain the correct concentrations. The correct concentrations were entered in the final data records described in Appendix J, but the incorrect values of the emission factor were left in these records. The files containing only the model results are for the erroneous emission factors. These may be corrected by any user by applying the quotients in Table 36. The correction was made before any analyses were performed.

Table 36. Quotients of Correct MOBILE1 Emission Factor/Erroneous MOBILE1 Emission Factor

SITE	QUOTIENT
Houston At-grade	0.93
Dallas At-grade	0.91
San Antonio	0.94
El Paso	0.88

APPENDIX I

Calculation of Model Input Emission Factors for the GM Data Cases

The SF_6 tracer release rate for the GM data cases had to be converted to an emission factor suitable for model imput. The emission factor was calculated as

$$EF_{GM} = \frac{P(\text{mmHg}) \times R(\ell/\text{min})}{T(K)} \times K_1 \tag{I-1}$$

where EF_{GM} = emission factor in gm/veh mi

P = atmospheric pressure during sampling period

T = temperature during sampling period

K_1 = conversion factor

R = release rate of SF_6 tracer

K_1 is calculated as

$$K_1 = \frac{\text{gmol K}}{0.08205\ \ell\ \text{atm}} \times \frac{0.06805\ \text{atm}}{51.72\ \text{mmHg}} \times \frac{146\ \text{gm}\ SF_6}{\text{gmole}} \times \frac{\text{hr}}{80\ \text{km}} \tag{I-2}$$

$$\times \frac{60\ \text{min}}{\text{hr}} \times \frac{1.609\ \text{km}}{\text{mi}} \times \frac{1}{5462\ \text{veh}}$$

$$= 5.1723 \times 10^{-4}\ \text{K gm min}/\ell\ \text{mmHg mi veh}$$

In Eq. I-2, 80 km/hr is the speed of the vehicles passing the sampling point, and 5462 veh/hr is the rate at which vehicles were passing the sampling point. The emission factor was translated to an emission rate for use in HIWAY by multiplying by factor K_2, which is calculated as

$$K_2 = \frac{5462\ \text{veh}}{2\ \text{hr}} \times \frac{\text{hr}}{3600\ \text{sec}} \times \frac{\text{mi}}{5280\ \text{ft}} \times \frac{\text{ft}}{0.3048\ \text{m}} \tag{I-3}$$

$$= 4.714 \times 10^{-4}\ \text{veh mi/sec m}$$

In Eq. I-3, 5462 veh/2 hr is the traffic rate on one side of the track. The product $EF_{GM} \times K_2$ yields an emission rate of dimensions gm/m sec.

The above procedure yielded very small values for emission factors and rates. These were multiplied by several orders of magnitude in order to obtain the proper number of significant figures in the concentration values returned by the pollution models.

Since all of the models calculate concentration in units of ppm CO on the basis of the molecular weight of CO, and the GM data are in units of ppb SF_6, a conversion factor incorporating the difference in molecular weight, change to ppb units, and the order of magnitude adjustment was applied to the model output. For each model the conversion factor is calculated by

$$K_3 = \frac{146 \text{ gm } SF_6/\text{gmole}}{28 \text{ gm CO/gmole}} \times \frac{10^3 \text{ ppb}}{\text{ppm}} \times \frac{1}{10^a} \qquad \text{(I-4)}$$

where K_3 = the conversion factor

a = order of magnitude multiplier for input emission factor

After the models had been run, it was discovered that the methods of calculating K_1 and K_3 above are incorrect. The correct calculation of K_1 is

$$K_1' = \frac{\text{gmol K}}{0.08205 \text{ ℓ atm}} \times \frac{0.06805 \text{ atm}}{51.72 \text{ mmHg}} \times \frac{146 \text{ gm } SF_6}{\text{gmol}} \times \frac{1}{352 \text{ veh}} \qquad \text{(I-5)}$$

$$\times \frac{30 \text{ min}}{3.9 \text{ cycles}} \times \frac{\text{cycle}}{10 \text{ km}} \times \frac{1.609 \text{ km}}{\text{mi}}$$

$$= 8.23216 \times 10^{-3} \text{ K gm min/ℓ mmHg veh mi}$$

In Eq. I-5, 352 veh is the number of vehicles that were on the track at any one time, 3.9 cycles/30 min was the rate at which each vehicle lapped the track, and 10/cm/cycle is the length of one lap of the track.

Therefore $K' = 16 \times K_1$ (I-6)

K_3 should be calculated as

$$K_3' = \frac{28 \text{ gm CO/gmole}}{146 \text{ gm } SF_6/\text{gmole}} \times \frac{10^3 \text{ ppb}}{\text{ppm}} \times \frac{1}{10^a} \qquad \text{(I-7)}$$

Therefore

$$K_3' = \left(\frac{28}{146}\right)^2 \times K_3 \qquad \text{(I-8)}$$

$$= \frac{K_3}{5.214^2}$$

In order to obtain the correct predicted value of SF_6 concentration the following factor should be applied:

$$P' = P \times \frac{K'_1 \; K'_3}{K_1 \; K_3}$$

$$= P \times \frac{16 \; K_1 \; K_3}{K_1 \; K_3 \; 5.214^2} \qquad \text{(I-9)}$$

$$= P \times 0.558$$

where P = the model prediction using incorrect conversion factors

P' = the model prediction for the correct conversion factors

The above correction applies to the results for all models except HIWAY. K_2 for obtaining HIWAY emission rates was also calculated incorrectly. The correct calculation is

$$K'_2 = \frac{352 \text{ veh}}{\text{cycle}} \times \frac{3.9 \text{ cycle}}{30 \text{ min}} \times \frac{\text{min}}{60 \text{ sec}} \times \frac{\text{mi}}{1609 \text{ m}} \times \frac{1}{2 \text{ lanes}} \qquad \text{(I-10)}$$

$$K'_2 = 2.37 \times 10^{-4} \text{ veh mi/sec m}$$

Therefore, $K'_2 = 0.5 \times K_2$ and

$$P' = \frac{K'_1 \; K'_3 \; K'_2}{K_1 \; K_3 \; K_2} \times P \qquad \text{(I-11)}$$

$$P' = \frac{16 \; K_1 \; K_3 \; K_2}{K_1 \; K_3 \; 5.214^2 \; 2} \times P$$

$$P' = P \times 0.294$$

The erroneous results for each of the models for the GM predictions are stored on tape. Using the above conversion factors, they may be adjusted to the correct values. The location and format of the files containing only the model results are given in Appendix J. The correct concentrations were entered in the final data records described in Appendix J.

APPENDIX J

Locations, Identifications, and Formats of Model Input Data Sets, Model Results, and Combined Data Base and Model Prediction Records

Table 37. Input Data Sets for AIRPOL-4A

Tape: ZZ3893 or ZZ3896 (*)

SITE/DATA	FILE NAME	FILE NO
Dallas At-Grade	IRPOL.MOD.JUL2077	18
15-minute	IRPOL.MOD.JUL2177	19
San Antonio	IRPOL.MOD.OCT0777	20
15-minute	IRPOL.MOD.OCT1777	21
	IRPOL.MOD.OCT1877	22
Houston At-Grade	IRPOL.MOD.DEC0976	115
15-minute	IRPOL.MOD.MAY2676	116
El Paso	IRPOL.MOD.NOV1677	117
15-minute	IRPOL.MOD.NOV1777	118
	IRPOL.MOD.NOV1877	119
	IRPOL.MOD.NOV2977	120
	IRPOL.MOD.NOV3077	121
	IRPOL.MOD.DEC0177	113
	IRPOL.MOD.DEC0377	114
GM		
	WC6.AIRPOL.GMDATA	244
Houston Cut	IRPOL.MOD.SEP0977	31*
15-minute	IRPOL.MOD.SEP1677	32*
	IRPOL.MOD.SEP2177	33*
	IRPOL.MOD.SEP2377	34*
	6.AIRPOL.MOD.1630	30*

Table 37. (cont'd)

SITE/DATA	FILE NAME	FILE NO
Dallas Elevated	WC6.AIRPOL.DALEL1	242
15-minute	WC6.AIRPOL.DALEL	243
Dallas At-Grade	NG.WEP.AIRPOL.DAG	15
5-minute mass balance		
San Antonio	NG.WEP.AIRPOL.SAN	25
5-minute mass balance		
Houston At-Grade	NG.WEP.AIRPOL.HAG	111
5-minute mass balance		
El Paso	IRPOL.MOD.ELPMASS	28*
5-minute mass balance		

The data sets for all models except TRAPS IIM for Dallas at-grade, San Antonio, and Houston at-grade mass balance cases contain AP-42 emission factors from Report 218-4. The El Paso mass balance data sets contain MOBILE1 emission factors from that report. The GM data sets for all models except TRAPS IIM cases include the erroneous emission factors. For the 15-minute cases, the emission factor for all models except TRAPS IIM is in error for all sites but El Paso, Houston Cut and Dallas elevated. The correct emission factors are given in Report 218-4.

Table 38. Predicted Concentrations for AIRPOL-4A

Tape: ZZ3893 or ZZ3896 (*)

FORMAT	SITE/DATA	FILE NAME	FILE NO
F1	Dallas At-Grade	OL.MODRES.JUL2077	178
F1	15-minute	OL.MODRES.JUL2177	179
F1	San Antonio	OL.MODRES.OCT0777	186
F1	15-minute	OL.MODRES.OCT1777	187
F1		OL.MODRES.OCT1877	188
F1	Houston At-Grade	OL.MODRES.DEC0976	177
F1	15-minute	OL.MODRES.MAY2676	180
F1	El Paso	OL.MODRES.NOV1677	181
F1	15-minute	OL.MODRES.NOV1777	182
F1		OL.MODRES.NOV1877	183
F1		OL.MODRES.NOV2977	184
F1		OL.MODRES.NOV3077	185
F1		OL.MODRES.DEC0177	175
F1		OL.MODRES.DEC0877	176
F2	GM	DH.WC6.GM.AIRPOL	275
F3	Houston Cut 15-minute	WC6.HOUCUT.AIRPOL	299
F3	Dallas Elevated 15-minute	WC6.DALEL.AIRPOL	58*

Table 38. (cont'd)

FORMAT	SITE/DATA	FILE NAME	FILE NO
F4	Dallas At-Grade 5-minute mass balance	WYL.NG.WC6.DALFIV	58*
F4	San Antonio 5-minute mass balance	WYL.NG.WC6.SANFIV	98*
F4	Houston At-Grade 5-minute mass balance	WYL.NG.WC6.HOUFIV	89*
F1	El Paso 5-minute mass balance	POL.MODRES.ELPASO	35*

Formats for Model Results

Format F1

CONCENTRATION FOR:	COLUMNS	FORMAT
CO1L	1-5	F 5-3
CO1H	6-10	F 5-3
CO2L	11-15	F 5-3
CO2H	16-20	F 5-3
CO3L	21-25	F 5-3
CO3H	26-30	F 5-3
CO4L	31-35	F 5-3
CO4H	36-40	F 5-3
CO5L	41-45	F 5-3
CO5H	46-50	F 5-3
Identifier	71-80	A 10

For the El Paso 5-minute mass balance cases the concentrations are for MOBILE1 emission factors only.

Format F2

Two lines per averaging period.

Line 1: unformatted values for T1L, T1M, T1H, T2L, T2M, T2H, T3L, T3M, T3H, T4L, T4M, T4H, T5L, T5M; line 2: unformatted values for T5H, T6L, T6M, T6H, T7L, T8L, IDENTIFIER - Columns 71-80

Format F4

VARIABLE	COLUMNS	FORMAT
Date	1-6	A6 (I6)
Time	8-11	I4
Wind speed at 10 m (mi/hr)	13-16	F 4.1
Wind angle wrt roadway (degrees)	18-19	I2
Stability class	21	I1
Traffic volume (veh/hr)	24-27	I4
Location	29-32	A4

Concentrations are unformatted beginning in column 33: measured CO, TRAPS II prediction, CALINE-2 prediction, HIWAY prediction, AIRPOL-4A prediction, TRAPS IIM prediction, identifier.

Identifier has a value of "1" or "2". "1" indicates the predicted concentrations are for the AP-42 emission factors listed by Bullin in Report 218-4. An exception is that the TRAPS IIM prediction is for the MOBILE1 emission factor listed in that report. "2" indicates that the predicted concentrations are for the experimentally determined emission factor.

Format F5 is the same as Format F2, except that line 2 has values for T5H, T6L, T6M, T6H, T7L, T7M, T7H, T8L, T8M, T8H, IDENTIFIER columns 71-80.

The results for the GM cases are for the erroneous emission factor.

The results for the 15-minute cases, except for the El Paso, Houston cut, and Dallas elevated sites, are for the AP-42 emission factor.

Table 39. Input Data Sets for CALINE-2

Tape: ZZ3893 or ZZ3896 (*)

SITE/DATA	FILE NAME	FILE NO
Dallas At-Grade	ALINE.MOD.JUL2077	129
15-minute	ALINE.MOD.JUL2177	130
San Antonio	ALINE.MOD.OCT0777	137
15-minute	ALINE.MOD.OCT1777	138
	ALINE.MOD.OCT1877	139
Houston At-Grade	ALINE.MOD.DEC0976	128
15-minute	ALINE.MOD.MAY2676	131
El Paso	ALINE.MOD.NOV1677	132
15-minute	ALINE.MOD.NOV1777	133
	ALINE.MOD.NOV1877	134
	ALINE.MOD.NOV2977	135
	ALINE.MOD.NOV3077	136
	ALINE.MOD.DEC0177	126
	ALINE.MOD.DEC0377	127
GM	WC6.CALINE.GMDATA	254
Houston Cut	ALINE.MOD.SEP0977	262
15-minute	ALINE.MOD.SEP1677	263
	ALINE.MOD.SEP2177	264
	ALINE.MOD.SEP2377	265

Table 39. (cont'd)

SITE/DATA	FILE NAME	FILE NO
Dallas Elevated 15-minute	WC6.CALINE.DALEL	253
Dallas At-Grade 5-minute mass balance	NG.WEP.CALINE.DAG	125
San Antonio 5-minute mass balance	NG.WEP.CALINE.SAN	46
Houston At-Grade 5-minute mass balance	NG.WEP.CALINE.HAG	30
El Paso 5-minute mass balance	ALINE.MOD.ELPMASS	47*

Table 40. Predicted Concentrations for CALINE-2

Tape: ZZ3893 or ZZ3896 (*)

FORMAT	SITE/DATA	FILE NAME	FILE NO
F1	Dallas At-Grade	NE.MODRES.JUL2077	39
F1	15-minute	NE.MODRES.JUL2177	40
F1	San Antonio	NE.MODRES.OCT0777	196
F1	15-minute	NE.MODRES.OCT1777	197
F1		NE.MODRES.OCT1877	198
F1	Houston At-Grade	NE.MODRES.DEC0976	138
F1	15-minute	NE.MODRES.MAY2676	141
F1	El Paso	NE.MODRES.NOV1677	191
F1	15-minute	NE.MODRES.NOV1777	192
F1		NE.MODRES.NOV1877	193
F1		NE.MODRES.NOV2977	194
F1		NE.MODRES.NOV3077	195
F1		NE.MODRES.DEC0177	189
F2		NE.MODRES.DEC0377	190
F5	GM	DH.WC6.GM.CALINE	276
F3	Houston Cut 15-minute	WC6.HOUCUT.CALINE	300
F3	Dallas Elevated 15-minute	WC6.DALEL.CALINE	274

Table 40. (cont'd)

FORMAT	SITE/DATA	FILE NAME	FILE NO
F4	Dallas At-Grade 5-minute mass balance	WYL.NG.WC6.DALFIV	58*
F4	San Antonio 5-minute mass balance	WYL.NG.WC6.SANFIV	95*
F4	Houston At-Grade 5-minute mass balance	WYLNG.WC6.HOUFIV	89*
F1	El Paso 5-minute mass balance	INE.MODRES.ELPASO	50*

Table 41. Input Data Sets for HIWAY

Tape: ZZ3893 or ZZ3896 (*)

SITE/DATA	FILE NAME	FILE NO
Dallas At-Grade	HIWAY.MOD.JUL2077	61
15-minute	HIWAY.MOD.JUL2177	62
San Antonio	HIWAY.MOD.OCT0777	67
15-minute	HIWAY.MOD.OCT1777	68
	HIWAY.MOD.OCT1877	69
Houston At-Grade	HIWAY.MOD.DEC0976	201
15-minute	HIWAY.MOD.MAY2676	202
El Paso	HIWAY.MOD.NOV1677	145
15-minute	HIWAY.MOD.NOV1777	63
	HIWAY.MOD.NOV1877	64
	HIWAY.MOD.NOV2977	65
	HIWAY.MOD.NOV3077	66
	HIWAY.MOD.DEC0177	59
	HIWAY.MOD.DEC0377	60
GM	WC6.HIWAY.GMDATA	279
	H.WC6.HIWAY.GMNEW	280
	H.WC6.HIWAY.GMN06	281
Houston Cut	HIWAY.MOD.SEP0977	282
15-minute	HIWAY.MOD.SEP1677	283
	HIWAY.MOD.SEP2177	284
	HIWAY.MOD.SEP2377	285

Table 41. (cont'd)

SITE/DATA	FILE NAME	FILE NO
Dallas At-Grade	NG.WEP.HIWAY.DAG	56
5-minute mass balance		
San Antonio	NG.WEP.HIWAY.SAN	73
5-minute mass balance		
Houston At-Grade	NG.WEP.HIWAY.HAG	57
5-minute mass balance		
El Paso	HIWAY.MOD.ELPMASS	82*
5-minute mass balance		

Table 42. Predicted Concentrations for HIWAY

Tape: ZZ3893 or ZZ3896 (*)

FORMAT	SITE/DATA	FILE NAME	FILE NO
F1	Dallas At-Grade	AY.MODRES.JUL2077	206
F1	15-minute	AY.MODRES.JUL2177	207
F1	San Antonio	AY.MODRES.OCT0777	214
F1	15-minute	AY.MODRES.OCT1777	215
F1		AY.MODRES.OCT1877	216
F1	Houston At-Grade	AY.MODRES.DEC0976	205
F1	15-minute	AY.MODRES.MAY2676	208
F1	El Paso	AY.MODRES.NOV1677	209
F1	15-minute	AY.MODRES.NOV1777	210
F1		AY.MODRES.NOV1877	211
F1		AY.MODRES.NOV2977	212
F1		AY.MODRES.NOV3077	213
F1		AY.MODRES.DEC0177	203
F1		AY.MODRES.DEC0377	204
F2	GM	L.DH.WC6.GM.HIWAY	277
F3	Houston Cut 15-minute	WC6.HOUCUT.HIWAY	301
F4	Dallas At-Grade 5-minute mass balance	WYL.NG.WC6.DALFIV	58*

Table 42. (cont'd)

FORMAT	SITE/DATA	FILE NAME	FILE NO
F4	San Antonio 5-minute mass balance	WYL.NG.WC6.SANFIV	98*
F4	Houston At-Grade 5-minute mass balance	WYL.NG.WC6.HOUFIV	89*
F1	El Paso 5-minute mass balance	WAY.MODRES.ELPASO	84*

Table 43. Input Data Sets for TRAPS II

Tape: ZZ3893 or ZZ3896 (*)

SITE/DATA	FILE NAME	FILE NO
Dallas At-Grade	TRAPS.MOD.JUL2077	163
15-minute	TRAPS.MOD.JUL2177	164
San Antonio	TRAPS.MOD.OCT0777	100
15-minute	TRAPS.MOD.OCT1777	171
	TRAPS.MOD.OCT1877	101
Houston At-Grade	TRAPS.MOD.DEC0976	162
15-minute	TRAPS.MOD.MAY2676	165
El Paso	TRAPS.MOD.NOV1677	166
15-minute	TRAPS.MOD.NOV1777	167
	TRAPS.MOD.NOV1877	168
	TRAPS.MOD.NOV2977	169
	TRAPS.MOD.NOV3077	170
	TRAPS.MOD.DEC0177	160
	TRAPS.MOD.DEC0377	161
GM	WC6.TRAPS.GMDATA	286
Dallas At-Grade	NG.WEP.TRAPS.DAG	157
5-minute mass balance		
San Antonio	NG.WEP.TRAPS.SAN	110
5-minute mass balance		

Table 43. (cont'd)

SITE/DATA	FILE NAME	FILE NO
Houston At-Grade	NG.WEP.TRAPS.HAG	97
5-minute mass balance		
El Paso	TRAPS.MOD.ELPMASS	109*
5-minute mass balance		

Table 44. Predicted Concentrations for TRAPS II

Tape: ZZ3893 or ZZ3896 (*)

FORMAT	SITE/DATA	FILE NAME	FILE NO
F1	Dallas At-Grade	PS.MODRES.JUL2077	104
F1	15-minute	PS.MODRES.JUL2177	105
F1	San Antonio	PS.MODRES.OCT0777	225
F1	15-minute	PS.MODRES.OCT1777	226
F1		PS.MODRES.OCT1877	227
F1	Houston At-Grade	PS.MODRES.DEC0976	103
F1	15-minute	PS.MODRES.MAY2676	106
F1	El Paso	PS.MODRES.NOV1677	220
F1	15-minute	PS.MODRES.NOV1777	221
F1		PS.MODRES.NOV1877	222
F1		PS.MODRES.NOV2977	223
F1		PS.MODRES.NOV3077	224
F1		PS.MODRES.DEC0177	218
F1		PS.MODRES.DEC0377	219
F5	GM	L.DH.WC6.GM.TRAPS	278
F4	Dallas At-Grade 5-minute mass balance	WYL.NG.WC6.DALFIV	58*
F4	San Antonio 5-minute mass balance	WYL.NG.WC6.SANFIV	98*

Table 44. (cont'd)

FORMAT	SITE/DATA	FILE NAME	FILE NO
F4	Houston At-Grade 5-minute mass balance	WYL.NG.WC6.HOUFIV	89*
F1	El Paso 5-minute mass balance	APS.MODRES.ELPASO	112*

Table 45. Input Data Sets for TRAPS IIM

Tape: ZZ3896

SITE/DATA	FILE NAME	FILE NO
Dallas At-Grade	RAPS3.MOD.JUL2077	127
15-minute	RAPS3.MOD.JUL2177	128
San Antonio	RAPS3.MOD.OCT0777	135
15-minute	RAPS3.MOD.OCT1777	136
	RAPS3.MOD.OCT1877	137
Houston At-Grade	RAPS3.MOD.DEC0976	126
15-minute	RAPS3.MOD.MAY2676	129
El Paso	RAPS3.MOD.NOV1677	130
15-minute	RAPS3.MOD.NOV1777	131
	RAPS3.MOD.NOV1877	132
	RAPS3.MOD.NOV2977	133
	RAPS3.MOD.NOV3077	134
	RAPS3.MOD.DEC0177	124
	RAPS3.MOD.DEC0377	125
GM	WC6.TRAPS3.GMDATA	121
Dallas At-Grade	NG.WCG.TRAPS3.DAG	118
5-minute mass balance		

Table 45. (cont'd)

SITE/DATA	FILE NAME	FILE NO
San Antonio 5-minute mass balance	NG.WC6.TRAPS3.SAN	155
Houston At-Grade 5-minute mass balance	NG.WC6.TRAPS3.HAG	122
El Paso 5-minute	NG.WC6.TRAPS3.ELP	119

Table 46. Predicted Concentrations for TRAPS IIM
Tape: ZZ3896

FORMAT	SITE/DATA	FILE NAME	FILE NO
F1	Dallas At-Grade	S3.MODRES.JUL2077	142
F1	15-minute	S3.MODRES.JUL2177	143
F1	San Antonio	S3.MODRES.OCT0777	152
F1	15-minute	S3.MODRES.OCT1777	153
F1		S3.MODRES.OCT1877	154
F1	Houston At-Grade	S3.MODRES.DEC0976	140
F1	15-minute	S3.MODRES.MAY2676	146
F1	El Paso	S3.MODRES.NOV1677	147
F1	15-minute	S3.MODRES.NOV1777	148
F1		S3.MODRES.NOV1877	149
F1		S3.MODRES.NOV2977	150
F1		S3.MODRES.NOV3077	151
F1		S3.MODRES.DEC0177	138
F1		S3.MODRES.DEC0377	139
F2	GM	TRAPS3.MODRES.GM	141
F4	Dallas At-Grade 5-minute mass balance	WYL.NG.WC6.DALFIV	58
F4	San Antonio 5-minute mass balance	WYL.NG.WC6.SANFIV	98

Table 46. (cont'd)

FORMAT	SITE/DATA	FILE NAME	FILE NO
F4	Houston At-Grade 5-minute mass balance	WYL.NG.WC6.HOUFIV	89
F2	El Paso 5-minute mass balance (MOBIEL1 emission factors)	PS3.MODRES.MASMOB	145
F1	El Paso 5-minute mass balance (calculated emission factors)	PS3.MODRES.MASMEA	144

Table 47. Combined Data Base and Model Prediction Records for Texas 15-Minute and GM Cases

Tape: ZZ3893

FILE NAME	SAS DATA SET NAME	FILE NO.
NG.WC6.RESULT.HAG	HAGRSLT	94
NG.WC6.RESULT.DAG	DAGRSLT	91
.NG.WC6.RESULT.SA	SANRSLT	96
.NG.WC6.RESULT.EP	EPRSLT	93
YL.NG.WC6.GMMODS1	GMMODELS	74
WC6.RESULT.DALELV	DELVRSLT	92
WC6.RESULT.HOUCUT	HCTURSLT	95

The records for the first four files in Table 47 contain information described in Table 32 in Appendix D. The records also contain variables named AIRPOL, CALINE, HIWAY, TRAPS, AND TRAPS IIM, which are the model predictions. The records for the GM file contain information as described in Appendix E. The records for the last two files contain information similar to the first four except that no value for TRAPS IIM has been entered.

All information in these records is correct except for emission factors. All concentrations have been adjusted to account for the bad emission factors.

APPENDIX K

Nomenclature

C - concentration

CO - carbon monoxide concentration

CO_m - mass flux of CO (gm CO/m^2 hr)

EF - emission factor (M/veh L)

F - conversion factor

g - gravitational constant (L/t^2)

H - source height (L)

h_c - average height at surface roughness element (L)

k - von Karman's constant (=0.4)

K_y - eddy diffusivity in $\bar{y}$ (crosswind) direction (L^2/t)

K_z - eddy diffusivity in $\bar{z}$ (vertical) direction (L^2/t)

K_1 - vertical eddy diffusivity at reference height (L^2/t)

L' - Monin-Obukhov length (L)

m - power law velocity exponent

n - power law eddy diffusivity exponent

P - predicted concentration

Q - point source strength

Q' - line source strength

Ri - Richardson's number

SF6 - SF_6 concentration

STAB - Turner stability class

t - time

T - temperature

u - wind velocity (L/t)

u_1 - reference wind velocity (L/t)

u_x - wind velocity perpendicular to roadway (L/t)

u_z - wind velocity at height $z > z_o$ (L/t)

u_* - friction velocity (L/t)

VOL - traffic volume on roadway (veh/t)

W - roadway width (L)

x - downwind distance (L)

x' - virtual orgin distance (L)

X_i - emperically determined concentration at the road edge

y - crosswind distance (L)

z - height (L)

z_o - roughness height (L)

z_1 - reference height (L)

σ_y - horizontal dispersion parameter (L)

σ_{y_o} - initial (road edge) value of σ_y (L)

σ_z - vertical dispersion parameter (L)

σ_{z_o} - initial (road edge) value of σ_z (L)

θ - acute angle of wind direction with respect to the roadway