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Multiple-Aircraft Instantaneous Line Source (MAILS) Dispersion Model User's Guide

E. J. Liebsch

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Energy Division

MULTIPLE-AIRCRAFT INSTANTANEOUS LINE SOURCE (MAILS) DISPERSION MODEL USER'S GUIDE

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ABBREVIATIONS, ACRONYMS, AND INITIALISMS

CAA	Clean Air Act
CFR	Code of Federal Regulations
CO	carbon monoxide
EPA	U.S. Environmental Protection Agency
GEIS	Generic Environmental Impact Statement
HC	hydrocarbons
ISCST	Industrial Source Complex, Short-Term (model)
LPT1	a printer port designation
MAILS	Multiple-Aircraft Instantaneous Line Source (model)
MOA	military operations area
MTR	military training route
NAAQS	National Ambient Air Quality Standards
NO_2	nitrogen dioxide
PART	particulate matter
PC	personal computer
PM-10	particulate matter fewer than 10 μm in diameter
PSD	Prevention of Significant Deterioration (of air quality)
RA	restricted area
SAILS	Single-Aircraft Instantaneous Line Source (model)
SO_2	sulfur dioxide
USAF	U.S. Air Force

EXECUTIVE SUMMARY

This document serves as a user's guide for the Multiple Aircraft Instantaneous Line Source (MAILS) atmospheric-dispersion model computer software. MAILS is an air-quality screening model that provides conservative estimates of ground-level pollutant concentrations resulting from aircraft engine emissions along low-altitude (under 3000 ft) military training routes (MTRs).

The MAILS model was developed to evaluate the air-quality impacts of proposed MTRs, in accordance with the environmental-impact analysis requirements of the National Environmental Policy Act of 1969 (NEPA, Pub. L. 91-190). Previous analyses indicated that the air-quality impacts of low-flying aircraft were potentially significant with respect to Prevention of Significant Deterioration (PSD) Class I pollutant increments (applicable primarily in certain national parks and wilderness areas) and were insignificant with respect to National Ambient Air Quality Standards and PSD Class II increments.

Existing air-quality models were deemed inadequate for application to the instantaneous line-source emissions produced by intermittent aircraft flights along MTRs. Therefore, the MAILS model was created for this unique type of pollutant source. The model was integrated with an aircraft-engine-emissions database to produce an interactive, user-friendly modeling system.

Validation of the MAILS model using actual ground-level concentration measurements was not feasible because of the lack of appropriate measurements and the technical difficulties in obtaining them. Therefore, a performance evaluation of MAILS was accomplished by comparing MAILS results with manually averaged results obtained from an existing, validated, atmospheric-dispersion model developed by the U.S. Environmental Protection Agency (EPA). The MAILS model test results closely agreed with the EPA model test results.

The MAILS output provides estimates of air-pollutant concentrations from proposed MTRs and comparisons of the concentrations with existing PSD Class I increments. The MAILS model can be run quickly and requires minimal user training to execute and to interpret or apply results. The model is recommended as a planning and assessment tool for those involved in the environmental-impact analysis process for proposed or existing low-altitude military airspaces.

PREFACE

This report was prepared by the Oak Ridge National Laboratory, P.O. Box 2008, Oak Ridge, TN 37831, under an Interagency Agreement (IAG) between the U.S. Department of Energy (DOE) and the Department of the Air Force (USAF) (DOE IAG No. 1489-1489-A1, USAF No. F88-52), for the Air Force Engineering and Services Center (AFESC), Engineering and Services Laboratory, Tyndall Air Force Base, FL.

This report summarizes work done between August 1988 and February 1990. Captain W. P. Chepren and Captain M. T. Moss were the AFESC/RDVS Project Officers.

1. INTRODUCTION

1.1 OBJECTIVE

This report provides instructions for the use of the Multiple-Aircraft Instantaneous Line Source (MAILS) atmospheric-dispersion model. MAILS is intended as a screening model for prediction of air-quality impacts of air-pollution emissions from low-flying aircraft on military training routes (MTRs). An air-quality screening model is generally defined as one that provides worst-case concentration estimates and can be run quickly with a minimum of user input. The MAILS model predictions of pollutant concentrations are considered to be worst-case estimates because of the assumptions incorporated in the model design.

1.2 BACKGROUND

The impetus for development of MAILS was the need to address the air-quality impacts of low-altitude MTRs as part of the environmental-assessment process required under the National Environmental Policy Act of 1969 (NEPA, Pub. L. 91-190). In accordance with NEPA, the U.S. Air Force (USAF) is preparing a Generic Environmental Impact Statement (GEIS) that addresses the impacts of establishing new low-altitude military airspaces. Potential air-quality impacts were assessed for the preliminary draft GEIS in part using the Single-Aircraft Instantaneous Line Source (SAILS) dispersion model (Ref. 1). The SAILS model was later modified by integrating an aircraft-emissions database and adding the capability for multiple-aircraft assessment in a single model run. The modified model was named MAILS.

An important finding from the modeling analysis conducted for the GEIS was that the air-quality impacts of low-flying military aircraft would be negligible (less than 5% of applicable air-quality standards) with respect to National Ambient Air Quality Standards (NAAQS) and Prevention of Significant Deterioration (PSD) Class II air-quality increments, which are applicable throughout most areas of the United States. The air-quality impacts of low-flying aircraft were determined to be potentially significant (possibly greater than 5% of applicable standards) with respect only to the more-stringent limitations applicable in PSD Class I areas (primarily national parks and wilderness areas larger than certain sizes). The increments of pollutant concentrations allowed in PSD Class I areas are generally one or more orders of magnitude lower than those allowed in other areas.

The current NAAQS and PSD Class II and Class I increments are shown in Appendix A. A listing and a map of current PSD Class I areas are shown in Appendix B. Standards occasionally change or are added, and new areas can be redesignated as PSD Class I. Therefore, the air-quality analyst is cautioned that appropriate state air-pollution-control agencies or U.S. Environmental Protection Agency (EPA) regional offices should be consulted periodically to obtain any information about new PSD Class I areas or increments.

An important aspect of the PSD program is that the allowable concentration increments apply only to major stationary pollutant sources. Low-flying aircraft, the emissions sources intended for analysis with the MAILS model, are not subject to any

of the regulatory-permitting and air-quality-analysis requirements (including PSD regulations) established pursuant to the Clean Air Act (CAA) and its amendments. The PSD Class I increments were established by the CAA Amendments of 1977 (Pub. L. 95-95) and apply only to major stationary sources of pollutant emissions. However, to satisfy the air-quality-impact analysis requirements of NEPA, measures established under the CAA (PSD increments and NAAQS) were applied to low-flying aircraft emissions to provide a standard for evaluating the significance of air-quality impacts (Ref. 1).

1.3 SCOPE

The types of airspaces considered in the preliminary draft GEIS for low-altitude flying operations included MTRs, military operations areas (MOAs), and restricted areas (RAs), among others. Existing atmospheric-dispersion models were judged appropriate for predicting ground-level pollutant concentrations caused by low-altitude flying operations within MOAs and RAs. Emissions from MOA and RA flying maneuvers were modeled as continuous area sources by means of the EPA Industrial Source Complex, Short-Term (ISCST) dispersion model (Ref. 2). However, for analysis of MTR pollutant impacts, the development of a new or modified model was deemed necessary. This decision was based on the characteristics of MTR emissions, which consist of intermittent, essentially instantaneous line sources. Therefore, the MAILS model was developed for application to MTRs or other airspaces or airspace segments that have consistent flight-path orientations similar to MTRs.

2. MODEL OVERVIEW

2.1 DISPERSION MODEL

MAILS is an interactive air-quality model that can be used for planning or environmental assessments of MTRs or similar low-altitude airspaces. Low altitude is defined here as fewer than 3000 ft above ground level. Low altitudes are consistent with the maximum altitude of operations addressed within the context of the GEIS and are also roughly the upper limit of the typical planetary boundary layer, within which atmospheric turbulence and diffusion are largely dependent on the action of wind and on solar insolation at the earth's surface. Most atmospheric-dispersion models are meant to be applied within this layer.

The dispersion algorithms used in MAILS are based on the commonly used Gaussian concentration distribution (Ref. 3). The line-source emissions are assumed to disperse and maintain Gaussian distributions in the horizontal (Y axis, perpendicular to line of release) and vertical directions. To obtain conservative concentration predictions, the wind direction is assumed to be parallel to the line of emissions release for 1 h. Concentration predictions for averaging periods longer than 1 h are based on the frequency of expected flights as input by the model user and on empirical averaging time adjustment factors to account for meteorological and flight-path variations throughout these longer periods.

2.2 AIRCRAFT-EMISSIONS DATABASE

The aircraft-emissions database contains data for roughly 50 military aircraft, including some non-USAF aircraft. The inclusion of non-USAF aircraft in the database is necessary for assessment purposes, because many low-altitude training routes are used by aircraft from more than one branch of the military. The emissions database can be updated easily through the menu-driven MAILS modeling system as emissions data for new aircraft, fuels, or engines become available.

The database contains a single record for each aircraft and pollutant combination. Because 5 pollutants are included in the current database, there are approximately 250 total database records. The pollutants represented in the database are sulfur dioxide (SO_2), nitrogen dioxide (NO_2), particulate matter (PART), carbon monoxide (CO), and hydrocarbons (HC). Only the first four pollutants are currently regulated by NAAQS, although HCs contribute to photochemical formation of ozone, for which an NAAQS has been set. Only SO_2, NO_2, and PART are regulated for PSD Class I areas. The NAAQS for PART are now set for particles fewer than 10 μm in diameter (PM-10). The PSD increments for PART are still applicable to total particulate matter, although EPA has recently issued a notice of proposed rule making to replace them with increments for PM-10 (see Appendix A).

2.3 MODEL/DATABASE INTEGRATION

A schematic of the MAILS model and database system is shown in Fig. 1. Several independent functions can be accomplished with this system: adding or editing database records; printing summary reports from the database; and executing the dispersion model, with results sent either to a disk file or a printer. The FoxBASE® Plus (Revision 2.0) database-management system was used to program the database-maintenance features and the model-input prompts. The executable (compiled with Microsoft® FORTRAN, Version 4.1) MAILS dispersion model was incorporated into this structure.

The integrated system allows the user to model in a single run the air-quality impact of a single pollutant for several aircraft types. The user simply chooses the pollutant to be modeled and the number of aircraft types for a given route segment. The system then displays a menu of aircraft-emissions data for selection and prompts for other necessary input, such as the frequency of flights, for the applicable averaging times.

2.4 COMPUTER-SYSTEM REQUIREMENTS

The MAILS modeling software can be run on systems meeting the following requirements:

- an IBM®-compatible PC-AT [or an upwardly compatible personal computer (PC) such as 80386-based machines] with a PC-DOS® or MS-DOS® (Version 3.0 or later) operating system;
- a color monitor;
- a math coprocessor (e.g., 80287, 80387);
- a minimum of 360 kB of free memory; and
- an Epson®-compatible dot-matrix printer (80-column), or a printer that can emulate the Epson® character set, that has a printer port designation of LPT1.

The MAILS software can be run from a flexible disk drive. However, the software should be copied to a hard disk if possible to improve response time considerably.

If the MAILS software is to be run from a hard disk, it is advisable to create a separate subdirectory and copy all files on the MAILS diskette to this subdirectory (see your operating system user's documentation or print the README.DOC file from the MAILS diskette for instructions).

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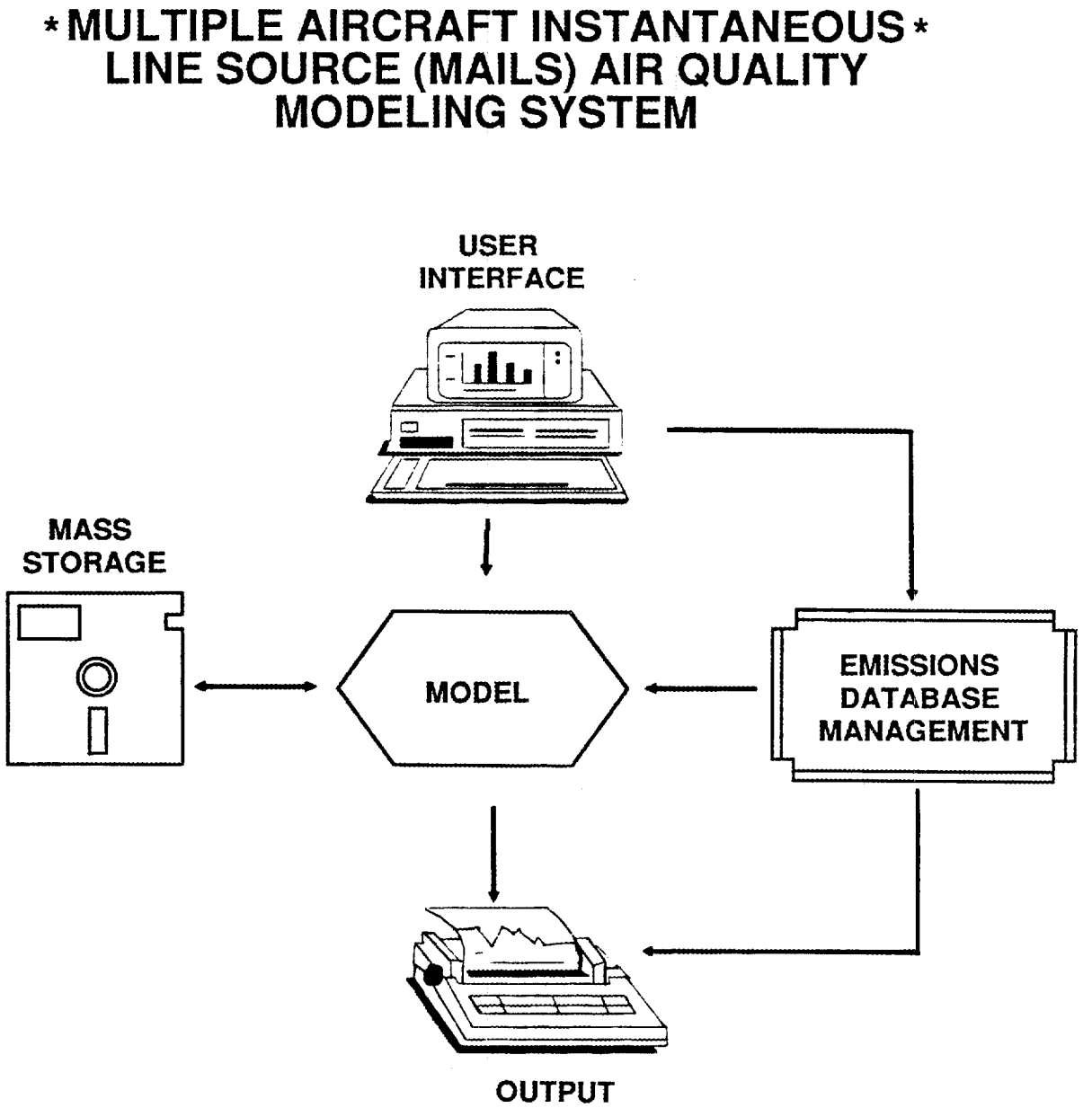

Fig. 1. A schematic of the MAILS model and database system.

3. TECHNICAL DESCRIPTION

3.1 DISPERSION MODEL

This section describes the design of the MAILS atmospheric-dispersion model, the formats of model input and output, and a model performance evaluation. A listing of the MAILS dispersion model FORTRAN computer code is provided in Appendix C.

3.1.1 Line-Source Simulation

The MAILS dispersion model calculates worst-case (maximum potential) 1-h concentrations for linear flight paths assumed to be parallel to wind direction. For a crosswind situation, a ground-level receptor would be affected only briefly after an aircraft passed, thereby registering much lower 1-h concentrations than in a parallel-wind case. Concentrations for averaging periods longer than 1 h are obtained by accounting for (1) the numbers of flights during these longer periods and (2) variations in meteorology and flight paths.

Emissions from a single flight path can be characterized as an essentially instantaneous, infinite line source. The MAILS model divides the instantaneous line source into puffs, each having a pollutant mass equal to the emissions contained in a 100-m-long segment of flight path. This dispersion modeling concept is illustrated in Fig. 2. For calculating the impacts of multiple flights along the same route path during periods of 1 h or longer, the model simply sums the calculated 1-h contributions from individual flights and applies averaging-period adjustment factors as described later in this section.

For a single aircraft pass, the MAILS model calculates the concentrations for an array of wind-speed/atmospheric-stability conditions and then selects the maximum concentration for any of these meteorological conditions. These 49 conditions are identical to those used in the PTPLU model (Ref. 4), which is an EPA-approved screening model for single, continuous point sources. The MAILS dispersion model assumes wind speed and direction to be constant in space and time.

Concentrations are computed for each wind speed/stability condition at a ground-level, plume-center-line location (receptor) by summing the contributions of all the puffs that pass the location in a 1-h period. The contributions to total exposure from puffs farther away than 1 h of travel time are expected to be small for most meteorological conditions and were not considered in obtaining maximum concentration estimates for periods longer than 1 h. Furthermore, because low-altitude wind directions are unlikely to remain constant for 1 h or more, the same receptor probably would not be exposed to impacts from the center line of the puffs/plume for longer periods. Thus, the concentrations calculated by the model for a single linear flight path are considered to be conservative (upper-bound) 1-h estimates.

3.1.2 Concentration Calculations

The MAILS model calculates concentrations by summing the exposures (products of concentration and time) from individual puffs that pass the receptor in a 1-h period and by converting the total exposure to a 1-h concentration. The mass of each puff is assumed to

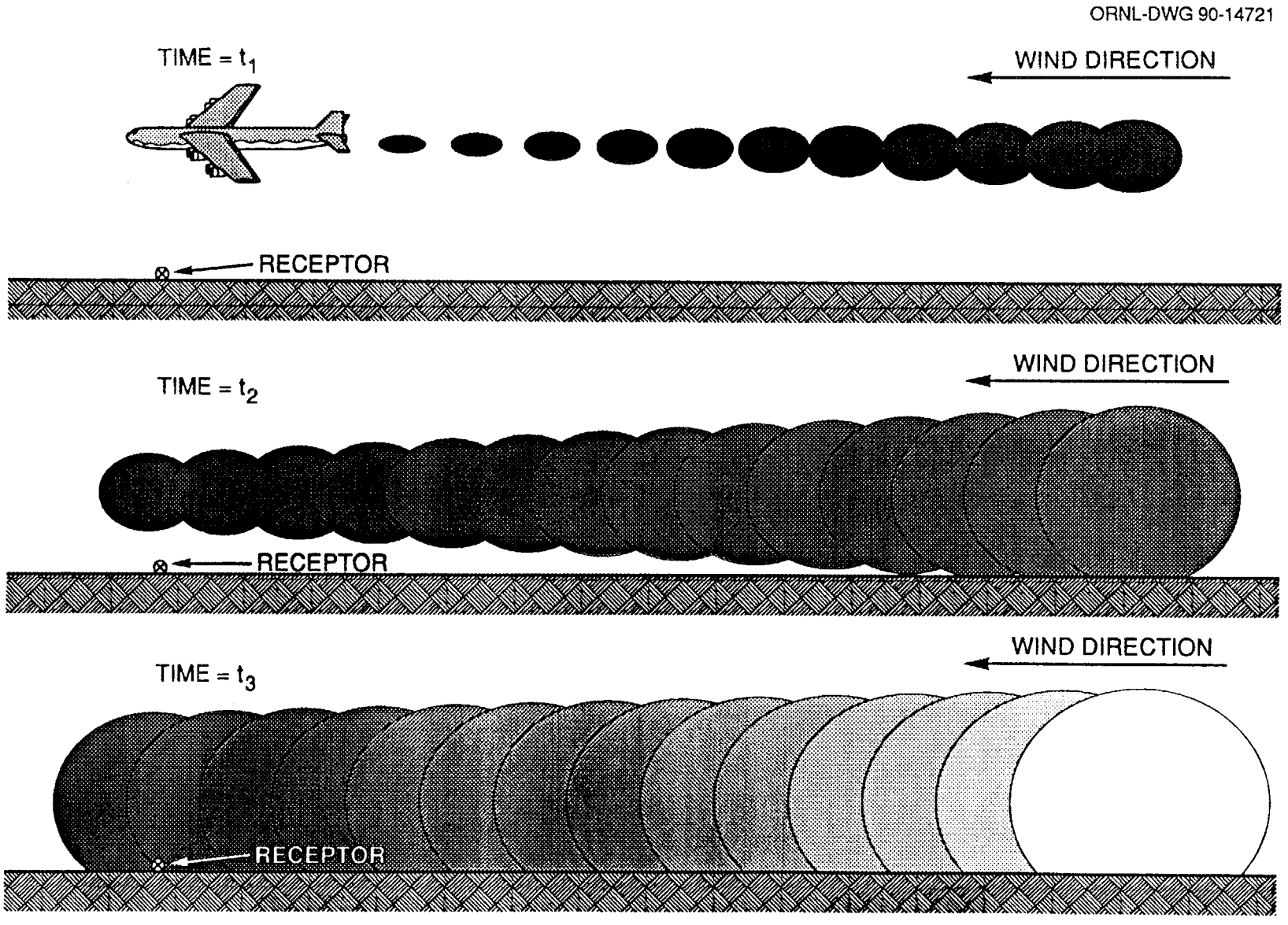

Fig. 2. Dispersion-modeling concept.

be distributed according to a Gaussian shape in the vertical (z) and horizontal (x and y) directions. The exposure ψ (g/m^3/s) from an individual puff is given by the following equation, which is taken from Slade (Ref. 5, p. 115):

$$\psi = \frac{Q}{\pi \sigma_y \sigma_z \bar{u}} \exp\left[-\left(\frac{y^2}{2\sigma_y{}^2} + \frac{h^2}{2\sigma_z{}^2} \right) \right] , \tag{1}$$

where Q is the puff mass (in g), σ_y is the standard deviation (in m) of the horizontal puff concentration distribution, σ_z is the standard deviation (in m) of the vertical puff concentration distribution, $\bar{u}$ is the average wind speed (in m/s), h is the emissions release height (in m) above ground level, and y is the perpendicular distance (in m) from the receptor to the plume center line. Because only the concentration on the plume center line (at ground level) is calculated by the MAILS model, y is 0 and the first term in the exponent becomes 0.

The preceding equation is appropriate for a situation that has essentially unlimited vertical atmospheric mixing. If limited mixing is important, the exponential term must be expanded to account for multiple reflections of the Gaussian vertical puff profile off the mixing height inversion and ground surfaces. In such cases, the exponential term is expanded in the same manner as that used by the ISCST model (Ref. 2). The ground-level plume-center-line exposure is then given by

$$\psi = \frac{Q}{\pi \sigma_y \sigma_z \bar{u}} \left\{ \exp\left[-\left(\frac{h}{2\sigma_z} \right)^2 \right] + \left[\sum_{n=1}^{\infty} \exp\left(-\left[\frac{2nH-h}{2\sigma_z} \right]^2 \right) + \exp\left(-\left[\frac{2nH-h}{2\sigma_z} \right]^2 \right) \right] \right\} , \tag{2}$$

where H is the surface mixing or inversion height.

At downwind distances for which the ratio of σ_z/H is greater than 1.6, the puff is essentially uniformly mixed in the vertical direction. The plume-center-line exposure from a single puff is then given by the equation

$$\psi = \frac{Q}{\pi \sigma_y \bar{u} H} . \tag{3}$$

The dispersion coefficients (σ_y and σ_z) used in the MAILS model are identical to those used by the EPA ISCST dispersion model (Ref. 2) when it is applied to point-source plumes without downwash-induced dispersion enhancement, in the *rural* mode. The use of the rural dispersion coefficients is considered appropriate for this application because the MTRs to which the MAILS model is applied would not cross over urban areas. It might

be argued that dispersion coefficients for puffs, which are somewhat smaller than those for continuous plumes, should be used in the MAILS model. However, it is appropriate to use dispersion coefficients for plumes rather than for puffs because the puffs are used by the model to simulate a continuous plume produced by the essentially instantaneous line-source emissions.

3.1.3 Averaging-Period Adjustments

Air-quality standards are typically established for averaging periods ranging from 1 h to 1 year (see Appendix A). The MAILS model estimates maximum concentrations for various averaging periods by summing the contributions of individual flights that would occur during the period of interest and by applying empirically derived averaging-period adjustment factors. The maximum concentration for a particular averaging period is given by

$$\chi = A \sum_{i=1}^{n} C_i F_i P \quad , \tag{4}$$

where χ is the maximum concentration ($\mu g/m^3$), n is the number of different aircraft/altitude combinations being modeled, C_i is the maximum 1-h concentration contribution ($\mu g/m^3$) from a single overflight for one aircraft/altitude combination, F_i is the frequency of overflights for one aircraft/altitude combination during the period of interest, P is the period of interest (in h), and A is the averaging-period adjustment factor for the period P. The averaging-period adjustment factors account for the variations in meteorological conditions and in the horizontal and vertical position of subsequent flights with respect to the route center line. These factors are subjective estimates based on dispersion modeling experience and on EPA recommendations (Ref. 6) for other types of pollutant sources. The averaging-period adjustment factors used for various periods are shown in Table 1.

The 3-h, 8-h, and 24-h factors are somewhat less than similar factors recommended by EPA for relating maximum 1-h concentrations to longer-period maximum concentrations for continuous elevated point sources (Ref. 6). The EPA factors are intended to account for variations in meteorological conditions that cause longer-term concentrations to be less than 1-h concentrations. However, the EPA factors were developed for continuous stationary sources, whereas the factors in Table 1 were developed for an intermittent source for which each successive emission varies in both horizontal and vertical position relative to a fixed ground-level receptor. The variation in horizontal and vertical position of the successive line sources creates greater effective dispersion of the emissions as averaging time increases, thereby lessening further the appropriate averaging-period adjustment factors.

The Table 1 averaging-period adjustment factors are not appropriate in situations that involve minimal flight frequencies. For example, if a maximum of one flight is expected in a 3-h period, flight-path variation does not apply, and variations in meteorological conditions throughout periods greater than 1 h are not relevant. In such a case, it would be appropriate to set A equal to 1.0. However, because routes with very low flight frequencies would generate negligible impacts with respect to PSD Class I

Table 1. Averaging-period adjustment factors

Averaging period	Factor
1 h	1.00
3 h	0.50
8 h	0.33
24 h	0.25
Annual	0.10

increments, this model limitation is not a problem for NEPA analyses or other applications for which PSD Class I increments are used as the measure of impact intensity.

3.1.4 Model Input

This section describes the input parameters required by the MAILS dispersion model. Some of these parameters can be selected from the emissions database or, at the user's option, edited upon selection of an aircraft-emissions record for a problem run without actual modification of the database file. Other parameters may have to be entered by the user, depending on the characteristics of the route segment to be modeled.

Table 2 lists the model input parameters in the sequence in which the user is prompted by the model. If the parameter type is shown as *D*, a default parameter is retrieved from the database when the user selects an aircraft-pollutant record from a menu and can be modified by the user before he or she enters it into the model. If the parameter type is *U*, the value for the parameter is a user input.

3.1.5 Output Description

The MAILS model output is sent either to a file named by the user during model input or directly to the printer. If the printer option is chosen, the default output device designation is LPT1. As a backup in case the printer cannot be accessed, the output is also sent to a file named MODEL.PRT when the printer option is chosen. The model output consists of summary tables for each of the applicable averaging periods. Each table shows all model input; the calculated concentration contributions by aircraft type/altitude combination; total concentration for the MTR segment or set of concurrent segments; and, if the standard run mode were selected, the calculated percentage of PSD Class I increment consumed by the modeled MTR segment(s). If the calculated percentage of Class I increment consumption is less than 5% for a given pollutant, the MTR segment(s) is considered to have a negligible impact with respect to that pollutant in the Class I area. A more-detailed discussion of the application of model output is contained in Sect. 4.2.

Table 2. Description of MAILS model input parameters

Parameter	Type[a]	Description
Title	U	User's description of the model run (e.g., airspace description, date of run)
Run mode	U	User can select standard (*S*) or nonstandard (*N*) mode. Choice of the *S* mode results in prompts for flight frequency (see frequency parameter below) for only the averaging periods and pollutants that have applicable air-quality standards (see Appendix A). Choice of the *N* mode results in prompts for frequency for 1-h, 3-h, 8-h, 24-h, and annual periods and allows modeling of other pollutants
Number of aircraft	U	This value is actually the number of aircraft/altitude combinations for the military training route (MTR) segment to be modeled. In nearly all situations, a given aircraft type is assigned only one minimum altitude for a given route or set of concurrent route segments
Pollutant	U	The database contains emissions data for five pollutants. A single pollutant (CO, NO_2, SO_2, PART, or other) is selected for a model run. Only three pollutants (SO_2, NO_2, and PART) must be considered for a PSD Class I analysis
Output option	U	The user enters *P*, to send output directly to the printer (a backup file named MODEL.PRT is also written in this case), or *F*, to send output to a file. If *F* is selected, the user is prompted for the file name
Aircraft	D	The aircraft designation (for example, "B-52G")
Airspeed	D	Average airspeed (mph) of the particular aircraft on MTR operations

Table 2. (continued)

Parameter	Type[a]	Description
Altitude	U	The minimum altitude (in ft) allowed for the particular aircraft on the MTR segment. If the minimum altitude is less than 200 ft, a value of 200 ft is recommended for input unless the aircraft consistently flies below this altitude
Mixing height	U	The height (in ft) of the surface-based temperature inversion. Use of the default value of 5000 ft (essentially unlimited vertical mixing) is recommended for most applications
Emission rate	D	Total emission rate (lb/h) of a single aircraft (all engines) for the selected pollutant
Frequency	U	Number of passes by the designated aircraft type on the route segment for each applicable averaging period, as determined by run mode and pollutant selection. For example, if the user selects *standard* for run mode and NO_2 for pollutant, the user is prompted only for an annual frequency, because only annual standards exist for NO_2. The user is cautioned that this is not always the same as the number of sorties (flights or missions). For example, some MTRs have racetrack portions, in which one aircraft may make several passes during a given sortie

[a]D = default parameter; U = user input.

3.1.6 Model Performance Evaluation

For many types of dispersion models, at least some field measurements are available for an objective assessment of model performance. However, for some types of models, the necessary field data do not exist and would be prohibitively expensive, if not impossible, to gather. This is the case with the MAILS dispersion model.

Limited field experiments have been conducted to measure ground-level concentrations produced by elevated instantaneous line sources. Such sources were simulated by tracers released from low-flying aircraft (Ref. 5, pp. 170–173). However, these experiments were configured so that the line of tracer release was perpendicular to the wind direction. Vertically spaced samplers mounted on a tower and a line of ground-based samplers downwind of the tracer releases recorded the concentrations produced by the tracer as it dispersed. The MAILS model dispersion algorithm simulates worst-case, short-term concentrations produced by an essentially instantaneous elevated release that is

parallel to the wind direction. Thus, as shown in Fig. 2, a fixed ground-level receptor beneath the plume center line would be exposed to emissions for a much longer period, as puffs originating from successively farther upwind locations continued to pass over the receptor. The difficulty in conducting a field experiment to measure such impacts would be in creating a tracer release so that the center line of the emissions would be exactly parallel to the wind direction for several miles upwind of, and in line with, a ground-based monitor (receptor).

Because of the lack of appropriate field data for model comparison, an alternative model-evaluation approach was utilized. This approach, in accord with general guidance provided by EPA (Ref. 7), consisted of comparing the results of the MAILS model with the results of the ISCST model (Ref. 2), which has already been the subject of a performance evaluation and which can be configured to simulate the type of source to which the MAILS model will be applied.

The following inputs and procedures were used to obtain ISCST results that could be compared with those produced by the MAILS model.

- Both models were run for a single source.
- ISCST comparison results were obtained using the rural dispersion mode and a wind speed of 10 m/s under two atmospheric stability categories [Pasquill C and D (see Ref. 3)], under both limited and unlimited mixing situations. Thus, four meteorological cases were generated for comparison.
- An ISCST emission rate was calculated, based on the 10 m/s wind speed, to provide the same linear emissions density produced by MAILS input for the comparison run.
- The ISCST structural downwash options were not used so that the Gaussian plume dispersion parameters would be the same as those used by the MAILS model.
- A 300-ft (91.5-m) stack source, with no plume rise (near-zero exit velocity and stack diameter) was simulated with ISCST to produce a plume of constant height.
- For the ISCST run, receptors were placed in the downwind direction every 500 m for 36 km, which would be the distance of puff transport in 1 h with the 10 m/s wind speed.
- The 72 concentration results produced by ISCST at the receptors described above were averaged to yield values for comparison with the MAILS output.

Use of the ISCST results in the preceding manner produces an average concentration at a receptor that is moving along the center line of a dispersing plume of constant linear density for 1 h. The MAILS model, on the other hand, simulates the concentration at a fixed receptor under the center line of a dispersing plume of constant linear density, which is assumed to move over the receptor for 1 h. Thus, these converse simulations should produce comparable results, as is shown in Table 3. The differences between the two model results are less than 5% for all cases, indicating that the MAILS model performs comparably with the ISCST (which is an existing validated dispersion model). This result is not unexpected, because identical dispersion coefficients are used in the MAILS model and in the ISCST model as executed for this comparison. Use of the ISCST model for routine air-quality analyses of MTRs is undesirable for several reasons: the ISCST model is noninteractive, ISCST requires more-detailed and -complex input than

Table 3. Comparison of multiple aircraft instantaneous line source and industrial source complex, short-term model results

Pasquill stability class ($\mu g/m^3$)	Mixing height (m)	MAILS concentration ($\mu g/m^3$)	ISCST concentration ($\mu g/m^3$)
C	122	5.072	5.069
C	5000	1.781	1.851
D	122	5.883	5.899
D	5000	3.493	3.501

does MAILS, ISCST is a much larger and therefore less portable program code than MAILS, and manual averaging of ISCST concentration estimates at many receptors was necessary to produce the values for comparison.

3.2 AIRCRAFT-EMISSIONS DATABASE

3.2.1 Parameters and Format

The aircraft-emissions database contains one record for each aircraft/pollutant combination. The parameters, with their formats and units, are listed in Table 4. Most of the parameters in Table 4 are self-explanatory. The emission rate is a product of the number of engines, the fuel rate per engine, and the emission factor, which is given in pounds of pollutant per 1000 lb of fuel. The emission-factor flag is a single character that is referenced to a separate file containing text to explain the source of each emission factor in the database.

The emissions density is not used by the model directly but was included in the database to allow the user to screen the emissions data visually to determine potential worst-case MTR segments. If the operating altitudes of two different aircraft were equal, the emissions densities for those aircraft would provide a comparison of relative ground-level concentration caused by the aircraft (i.e., if Aircraft A has an emissions density twice that of Aircraft B, the ground-level concentration caused by Aircraft A will be twice that caused by Aircraft B). When a record is added to the database, the database software automatically calculates the emissions density by dividing the emission rate by the average airspeed.

Table 4. Aircraft emissions database parameters

Parameter	Type	Field width	Decimal places	Units (if applicable)
Aircraft type	Character	8		
Average speed	Number	3	0	mph
Number of engines	Number	1	0	
Fuel rate per engine	Number	8	2	1000 lb fuel/h
Emission factor	Number	8	2	lb/1000 lb fuel
Emiss. factor flag	Character	1		
Pollutant	Character	4		
Emission rate	Number	8	2	lb/h
Emission density	Number	6	4	lb/mile

3.2.2 Emissions Data Sources

Most of the aircraft emissions data are based on emission factors and fuel rates drawn from Seitchek (Ref. 8). These data have been supplemented with data from other sources (Refs. 9–11). The SO_2 emission rates for all aircraft engines were calculated based on a fuel sulfur content of 0.05%, which is at the upper end of the spectrum of the numerous aviation-fuel test results reported by Shelton (Ref. 9). A separate emission-factor reference file contains a brief description of the data source or the assumptions used to obtain or calculate each emission factor. Each entry in the emission-factor reference file is identified by a one-character *flag* that corresponds with the emission-factor flag used in the main database.

Because air-pollutant-emission rates vary substantially with engine-throttle settings, it is important to choose data representative of the throttle settings used for typical low-altitude flights. The emission rates in the database are representative of the *intermediate* engine operating mode as discussed in Ref. 8. The intermediate mode was considered to be the most applicable to the type of cruising operations that would occur on most MTRs. However, data from other sources were not generally categorized using the same terminology used in Ref. 8. For these other sources, a data point was chosen that most closely corresponded to approximately 75% of the maximum throttle or fuel flow rate under normal engine operating conditions, apart from afterburner or other special modes not intended for continuous operation.

The emissions data from Seitchek and other sources are used in a conservative manner in the MAILS model. SO_2 emissions are based on complete conversion of the fuel sulfur to SO_2. NO_2 emissions are based on the assumption that all nitrogen oxides (NO and NO_2) are in the form of NO_2. Finally, total particulate-matter emissions are used to produce results for comparison against standards for PM-10. These conservative assumptions would typically result in SO_2 concentrations that are several percent higher than actual concentrations and in NO_2 and PM-10 concentrations as much as approximately two times higher than actual concentrations.

4. USING THE MODEL AND DATABASE

4.1 DATABASE MANIPULATIONS

Most of the aspects of database manipulation are easily understood by moving through the menu screens and, if necessary, using the *Help* options. However, explanations of some of the common types of manipulations are given in the following sections.

4.1.1 Editing, Adding, or Deleting Records

4.1.1.1 Emissions File

Emissions file records can be easily modified, added, or deleted by selecting the *Database Maintenance* feature from the MAILS master menu and the *Revise Emissions Database* feature from the Database Maintenance menu that follows. These menus are shown in Fig. 3. The program then prompts the user with a screen listing the various database parameters for the first record in the database. An example of this screen is shown in Fig. 4. The fields on this first screen cannot be modified at this point; they are intended only to give the user an indication of the type of data in the database. The user can use the menu features at the bottom of the screen to scan the existing data or to add, copy, modify, or delete records. For example, selecting the *add* feature clears the aircraft identification field and most of the other data fields, except for some default values. The user can then enter the desired data in the empty fields, concluding with the emission-factor flag. The user does not enter the emission rate when adding a record; the database computes this value automatically by taking the product of the fuel rate per engine (1000 lb/h), the number of engines, and the emission factor (lb of pollutant/1000 lb fuel).

Another way to add a record is to use the *copy* feature. This is especially useful when adding to the database a new record that is very similar to an existing record. In this case, the user scrolls through the database to retrieve the similar record to the screen. Selecting *copy* will cause these data to be copied to an identical data-entry screen and will allow the user to edit the parameters. When the cursor is moved to a point before the first data field or past the last data field, the software asks the user if the record is to be saved; if the user answers *Y*, the record is added to the permanent database.

An easy way to scan the database is to select the *Lst* feature and then use the up/down arrow keys or the page-up/page-down keys to scan the database quickly. If a record is highlighted with this feature, pressing the *Esc* key will cause this record to be retrieved to the single record display screen for possible manipulation.

A number of other useful features are included in the menu at the bottom of the single record display screen (Fig. 4). A one-line explanation is provided if a function is highlighted, which can be accomplished with the arrow keys. Also, if the user wants to select a particular function from this menu, he or she can either highlight the function and press *Enter* or can simply type the first letter of the desired function.

The *View* function allows the user to see the reference documentation for the emission factor. Documentation of the source of each emission factor in the database is contained in the emission-factor reference file. Editing and printing the emission-factor reference file is described in the following section.

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```
Air Quality Modeling System                                  * Master Menu *

                 MULTIPLE AIRCRAFT INSTANTANEOUS LINE SOURCE
                                 ( MAILS )

                          Run MAILS Model
                          DataBase Maintenance
                          Introductory Screen
                          Quit ...
```

```
Air Quality Modeling System                                  * Maint Menu *

                      ----- DATABASE MAINTENANCE -----

                     Revise Emissions DataBase
                     Emissions Flag Ref.
                     Manual Reindex Function
                     Print Emissions Database Summary
                     Help Screen Review
                     Quit ...
```

Fig. 3. MAILS master menu (top) and Database Maintenance menu (bottom).

ORNL-DWG 90-14723

```
Air Quality Modeling System                          Aircraft Emissions Data

    AIRCRAFT IDENTIFICATION --------> : A10
    AIRSPEED ----------------------> : 405  ( MPH )
    FUEL RATE PER ENGINE -----------> :     0.92 (1000 Lb/Hr)
    EMISSION FACTOR ----------------> :    16.30 (Lb/1000Lb)
    TYPE OF POLLUTANT --------------> : CO
    NUMBER OF ENGINES -------> : 2     EMISSION FLAG ---> : B
    EMISSION RATE -------------------> :    29.99 (Lb/Hr)

Ret/Beg/End/Nxt/Prv/Skp/Mod/Add/Cpy/Del/Lst/Filt/Tally/Help/View/Quit
Retrieve a record by its key fields
```

Fig. 4. Single-emissions record and menu.

4.1.1.2 Emission-Factor Reference File

This file documents the sources of various emission-factor data. If the emissions-data file is to be revised, the user should first print a summary of the emission-factor reference file and determine if one of the existing references in it can be used as a source for a new or revised emission file data. If one of the existing references can be used, the user should enter the corresponding single-character flag when the emissions record is added or revised. If none of the existing emission-factor references is appropriate for the new data, the user should add a new flag and explanation to the emission-factor reference file. This can be done by selecting the *Emission Flag Ref.* feature from the Database Maintenance screen (Fig. 3). The user will then be prompted by the Emissions Factor Document Reference menu (Fig. 5, top), from which the user can print a summary of the reference file (Summary Report option) or can revise the database (Database Maintenance option). If the latter is chosen, the screen shown at the bottom of Fig. 5 appears.

Adding, modifying, or deleting new flags is done in a manner similar to that used for the emissions-data file (see Sect. 4.1.1.1). Adding or editing the text that accompanies the flag is done differently. For example, to add a flag and accompanying reference text, the user selects the *Add* feature (see bottom of Fig. 5), and the software blanks out the Emissions Reference Flag field. After the desired flag is entered, the user is asked if he

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```
Air Quality Modeling System                          Document Ref. Menu

                    * Emissions Factor Document Reference *

                          DataBase Maintenance
                          Summary Report
                          Help Screen Review
                          Quit ...
```

```
Air Quality Modeling System                    Emission Factor Ref. DataBase

                    Emissions Reference Flag    : A
```

```
Ret/Beg/End/Nxt/Prv/Skp/Mod/Add/Cpy/Del/Lst/Filt/Tally/+/-/Help/Quit
Retrieve a record by its key fields
```

Fig. 5. Emissions-Factor Document reference menu (top) and Database-Maintenance option menu (bottom).

or she would like to edit the document area. If he or she answers *yes*, the screen depicted at the top of Fig. 6 appears. The user must then press the *Ctrl* and *Home* keys to display the text-entry screen, shown at the bottom of Fig. 6. After the desired text is entered, the user must press the *Ctrl* and *W* keys to write the text to the database record associated with the selected flag.

If the *Help* feature is chosen from the menu shown at the bottom of Fig. 5, a brief summary of the options and keystrokes needed to edit the Emission Factor Reference Database is provided.

4.1.2 Printing Database Summaries

To obtain a hard-copy listing of emissions data, the user must select the *Print Emissions Database Summary* option (Fig. 3) from the Database Maintenance menu. The user can then scan the data using the *Lst* and other options that will appear as shown on the top screen in Fig. 7. If *Go* is selected at this point, a tabular summary of all records in the emissions database is produced. However, the user can print a summary of a selected set of records by first selecting the *Filt*, or filter, option. A screen is then displayed on which certain database fields are empty, but highlighted. The entering of values for any of these fields will select only a portion of the database for the summary report. For example, entering *F1* in the Aircraft Identification field and SO_2 in the Pollutant field (bottom of Fig. 7) causes the filter to be set to select only SO_2 records for aircraft having *F1* as the first two characters. After the user spaces past the last open field on this screen, the screen shown at the top of Fig. 8 is displayed. If the *Go* option is selected, the report shown at the bottom of Fig. 8 is produced. Before listing the report, the software asks the user if the report is to be sent to either the screen or the printer.

Information from the Emissions-Factor Reference Database file can also be printed using procedures like those described previously for the Emissions Database. However, for the Emission-Factor Reference Database, only a single one-character field, the emission-factor flag, can be used to select or filter records to print. Therefore, the only possibilities are to print a single record from this file or to print all records. The report selection menu for this file is accessed by selecting *Emissions Flag Ref.* from the Database Maintenance menu (Fig. 3) and then *Summary Report* from the following menu (Fig. 4).

4.1.3 Reindexing the Emissions Database

Periodically, after the user has made a number of revisions or additions to the database, it is advisable to reindex the emissions database. Reindexing updates internal database index files, making database manipulations (such as sorting or searching) more efficient. Reindexing is performed by the database-management software and takes very little time. All that is required by the user to perform this function is to select the *Manual Reindex Function* item on the Database Maintenance menu. The software does the rest and very shortly returns control of the system to the user.

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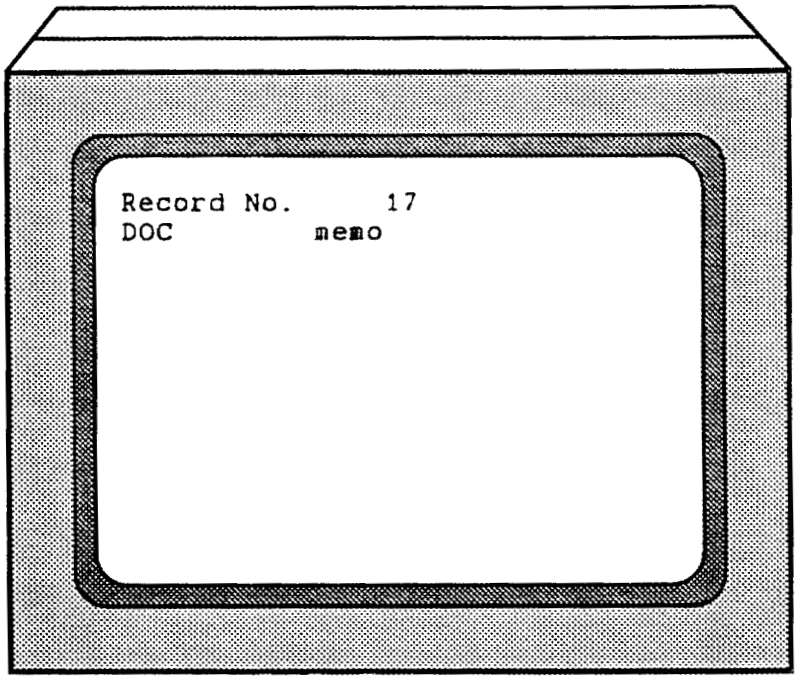

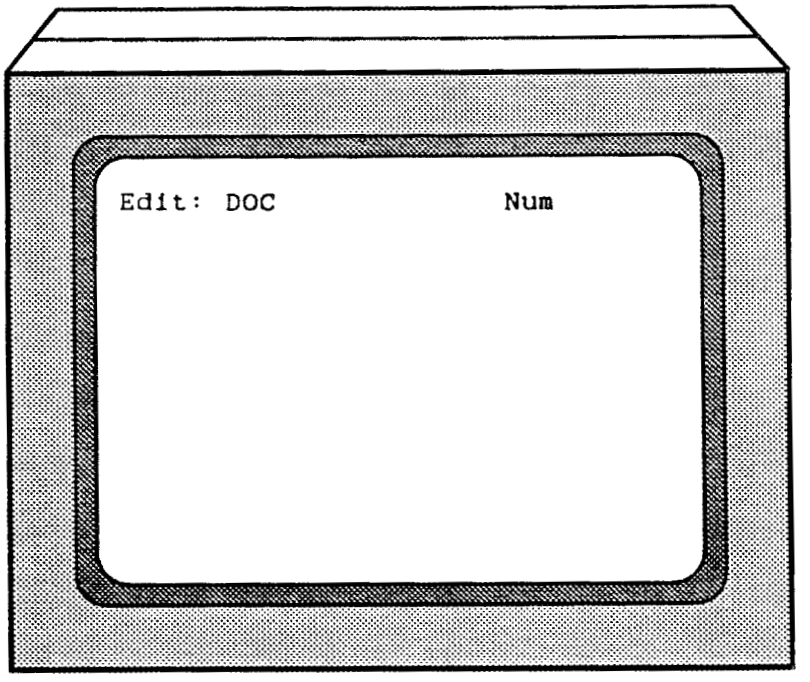

Fig. 6. Emissions-Factor Reference Document entry screen (top) and Text-Input screen (bottom).

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```
Air Quality Modeling System                                  Emissions Data Summary

        AIRCRAFT IDENTIFICATION --------> : A10

        AIRSPEED ----------------------> : 405  ( MPH )

        FUEL RATE PER ENGINE ----------> :     0.92 (1K Lbs/Hr)

        EMISSION FACTOR ---------------> :    16.30 (Lbs/1000Lbs)

        TYPE OF POLLUTANT -------------> : CO

        NUMBER OF ENGINES -------> : 2     EMISSION FLAG ---> : B

        EMISSION RATE ------------------> :          (Lbs/Hr)
Set - Filter : Off
First Record < A10   405
Last  Record > T47   100

Go/</>/Filt/Beg/End/Nxt/Prv/Skp/Lst/Tally/Help/Quit
Print or display the report
```

```
Air Quality Modeling System                                  Emissions Data Summary

        AIRCRAFT IDENTIFICATION --------> : F1

        AIRSPEED ----------------------> :      ( MPH )

        FUEL RATE PER ENGINE ----------> :     0.00 (1K Lbs/Hr)

        EMISSION FACTOR ---------------> :     0.00 (Lbs/1000Lbs)

        TYPE OF POLLUTANT -------------> : SO2

        NUMBER OF ENGINES -------> :       EMISSION FLAG ---> :

        EMISSION RATE ------------------> :     0.00 (Lbs/Hr)
Set - Filter : Off
First Record < A10   405
Last  Record > T47   100

Filter: Set/Cancel/Quit? S
```

Fig. 7. Emissions-Data Summary menu screen (top) and filter-setting screen (bottom).

ORNL-DWG 90-14726

```
Air Quality Modeling System                                  Emissions Data Summary

        AIRCRAFT IDENTIFICATION --------> : F106

        AIRSPEED ----------------------> : 520  ( MPH )

        FUEL RATE PER ENGINE ----------> :     8.64 (1K Lbs/Hr)

        EMISSION FACTOR ---------------> :     1.00 (Lbs/1000Lbs)

        TYPE OF POLLUTANT -------------> : SO2

        NUMBER OF ENGINES -------> : 1     EMISSION FLAG ---> : D

        EMISSION RATE -----------------> :     0.00 (Lbs/Hr)
Set - Filter : aircraft='F1' .and.pollutant='SO2'
First Record < A10   405
Last  Record > T47   100

Go/</>/Filt/Beg/End/Nxt/Prv/Skp/Lst/Tally/Help/Quit
Print or display the report
```

Page 1

MULTIPLE AIRCRAFT INSTANTANEOUS LINE SOURCE
EMISSIONS DATABASE SUMMARY

Air Craft Type	AVG Speed (MPH)	Fuel Rate 1 Engine (1000 Lb/Hr)	No. of Engines	Pollu Type	Emission Factor (Lb/1000 Lbs)	Emission Rate (Lb/Hr)
F106	520	8.64	1	SO2	1.00	8.64
F111A	550	4.93	2	SO2	1.00	9.86
F111D	550	5.71	2	SO2	1.00	11.42
F111E	550	4.93	2	SO2	1.00	9.86
F111F	550	7.16	2	SO2	1.00	14.32
F14	550	7.40	2	SO2	1.00	14.80
F15	550	5.11	2	SO2	1.00	10.22
F16	550	5.11	1	SO2	1.00	5.11
F18	550	7.50	2	SO2	1.00	15.00

Press any key to continue...

Fig. 8. Emissions-Data Summary screen, after filter has been set (top), **and resulting summary report** (bottom).

4.2 PERFORMING A MODEL RUN

4.2.1 Selecting Emissions Data for a Model Run

Selection of the *Run MAILS Model* option from the main menu will initiate the prompts for user input data to define the model run. A description of each input parameter is given in Sect. 3.1.4. After he or she enters some preliminary parameters, the user will be shown a listing of aircraft emissions for the previously selected pollutant. An example of this listing is shown for SO_2 at the top of Fig. 9. The user can scroll through these data to select a desired aircraft. When the desired aircraft is highlighted, the user selects it by pressing the *Esc* key. The data for the selected aircraft are then displayed on another screen (see bottom of Fig. 9) for possible editing, as are open fields requesting the appropriate flight-frequency data. As mentioned earlier, the emissions data on this screen can be edited without modifying the permanent database. After the user has verified that the data on this screen are correct, pressing *Enter* adds the record to a temporary file in preparation for the model run. If the user has selected multiple aircraft for the model run, the listing of aircraft emissions for the selected pollutant reappears. This process is repeated until the temporary file for model input contains a number of records that is equal to the number of aircraft types selected for the model run. The user is then shown a summary table with the data selected for model input and with an option to make a model run or to change the data. If the user verifies that the data are correct, model execution is initiated.

Dispersion-model run time depends on the type of computer and on the number of aircraft types selected but is relatively short. For example, on a 12-MHz, IBM®-compatible PC-AT, a run for three aircraft types would take approximately half a minute from the time the user completed the data-entry portion of the model run. Interpretation of the model output is explained in the following section.

4.2.2 Applying Results

An analysis of PSD Class I increment consumption is the intended application of the MAILS model. Because PSD Class I increments have been established for three pollutants (see Appendix A), a typical analysis for a Class I area would require three model runs: one each for SO_2, NO_2, and PART. If the user selects the *standard* operating mode for the model runs, the application of the model results is very simple. The model computes the amount of each PSD Class I increment consumed by the route analyzed and also the percentage of the allowable increment represented by the impact. Based on EPA regulations (40 CFR 51.167), impacts less than 5% of an allowable increment were considered to be insignificant (Ref. 1). No further analysis is required in such cases.

If the predicted incremental impact of any route segment is greater than 5% of an allowable Class I increment, the analyst should first verify that the model input values are not overly conservative (flight frequencies too high or altitudes too low). If the appropriate model input data have been used, further analysis (a cumulative impact assessment) may be required to determine the amount of Class I increments consumed by the combined impacts of the low-level route and other types of pollutant sources. The user should contact the appropriate local, state, or EPA air-pollution-control agency for information on existing PSD Class I increment consumption levels in such cases. If other sources have consumed increment in the PSD Class I area of interest, in most cases the

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AIRCRAFT	SPEED_MPH	ENGINE	FUEL_RATE	EM_FACTOR	EF	POLLUTANT	EM_RATE-	EM_DENSITY
A10	405	2	0.92	1.00	D	SO2	1.84	0.0045
A37	345	2	1.46	1.00	D	SO2	2.92	0.0085
A4	490	1	2.38	1.00	D	SO2	2.38	0.0049
A6	520	2	2.38	1.00	D	SO2	4.76	0.0092
A7	460	1	5.83	1.00	D	SO2	5.83	0.0127
AV8	520	1	7.10	1.00	F	SO2	7.10	0.0137
B1B	610	4	5.11	1.00	D	SO2	20.44	0.0335
B52G	400	8	6.69	1.00	D	SO2	53.52	0.1338
B52H	400	8	6.24	1.00	D	SO2	49.92	0.1248
C130	240	4	1.85	1.00	D	SO2	7.40	0.0308
C141	325	4	7.23	1.00	D	SO2	28.92	0.0890
C5	290	4	12.02	1.00	D	SO2	48.08	0.1658
F106	520	1	8.64	1.00	D	SO2	8.64	0.0166
F111A	550	2	4.93	1.00	D	SO2	9.86	0.0179
F111D	550	2	5.71	1.00	D	SO2	11.42	0.0208
F111E	550	2	4.93	1.00	D	SO2	9.86	0.0179
F111F	550	2	7.16	1.00	D	SO2	14.32	0.0260

BROWSE ||<H:>||MAILS ||Rec: 5/225 || ||

View and edit fields.

```
Air Quality Modeling System          SO2          Model Data Entry Screen

        AIRCRAFT TYPE            ----> A10
        AVG. AIR SPEED           ----> 405        MPH
        EMISSION RATE            ---->     1.84   Lb./Hr.
        RELEASE ALTITUDE         ---->            Feet
        MIXING (INVERSION) HEIGHT ----> 5000      Feet
          ----------------  FREQUENCY  -----------------
                     3Hr      24Hr      Annual

                     * Number of Aircraft *
```

Fig. 9. Emissions data for SO_2 (top) and Aircraft Data-Entry screen (bottom).

appropriate agency should have some model predictions that estimate the amounts of increment already consumed.

Application of the *nonstandard* model run mode may be necessary if air-quality standards change (for example, if a 24-h PSD Class I increment is developed for NO_2) or if for any reason the analyst wants to evaluate the impact of a pollutant for an averaging period not represented in the *standard* run mode. Also, the MAILS model can be used to evaluate impacts of other pollutants and aircraft types that have not been entered in the permanent database for any of the averaging periods (1-h, 3-h, 8-h, 24-h, and annual) represented in the *nonstandard* mode. This evaluation can be accomplished by entering *Other* for the pollutant type and by changing the data as appropriate on the data-entry screens (see bottom of Fig. 9).

4.3 EXAMPLE APPLICATIONS

The following examples show the types of data that need to be assembled before a modeling exercise; they illustrate how the user can focus the air-quality impact analysis on the MTR segments of greatest concern.

4.3.1 Example 1

Figure 10 shows a hypothetical set of MTR segments that pass over a PSD Class I area. Segments A and B are portions of individual routes that join to form a concurrent route segment (C) over the Class I area. Although three separate line sources exist over different parts of the Class I area, it is obvious that segment C would generate the greatest ground-level impacts, because it would have the greatest amount of traffic and because the minimum altitudes of the three route segments are equal. Therefore, only segment C would be modeled to determine the maximum impact with respect to PSD Class I increments.

Table 5 summarizes the aircraft altitude and frequency data that would be used for estimating the air-quality impacts of segment C. The other necessary model input data for these aircraft are selected from the emissions database. This hypothetical example assumes that there are no limitations on the mix of the four aircraft types that would be flown over segment C in any given 3-h or 24-h period. Therefore, it is important to assess the impacts of the worst-case aircraft type with regard to these short-term periods. The B-52H, the most frequently used aircraft on the route, has emissions densities of SO_2 and PM-10 (for which 24-h or 3-h estimates are necessary) that are roughly the same as or greater than those of the other aircraft. Therefore, the maximum 24-h and 3-h flight frequencies are based on the assumption that all flights during these periods could be made by B-52H aircraft. Because the emissions densities of various aircraft can be compared by consulting the emissions database (see Fig. 9, top), the 3-h and 24-h frequencies are entered as zero for the other aircraft types when the model runs are made for SO_2. Based on scheduling or other limitations, it is assumed that a B-52H could cross the route segment a maximum of 6 times in 3 h or 16 times in 24 h.

The analysis of PSD Class I increment consumption is accomplished with three model runs: one each for NO_2, SO_2, and PM-10. The model input and output for the SO_2 run are discussed for this example.

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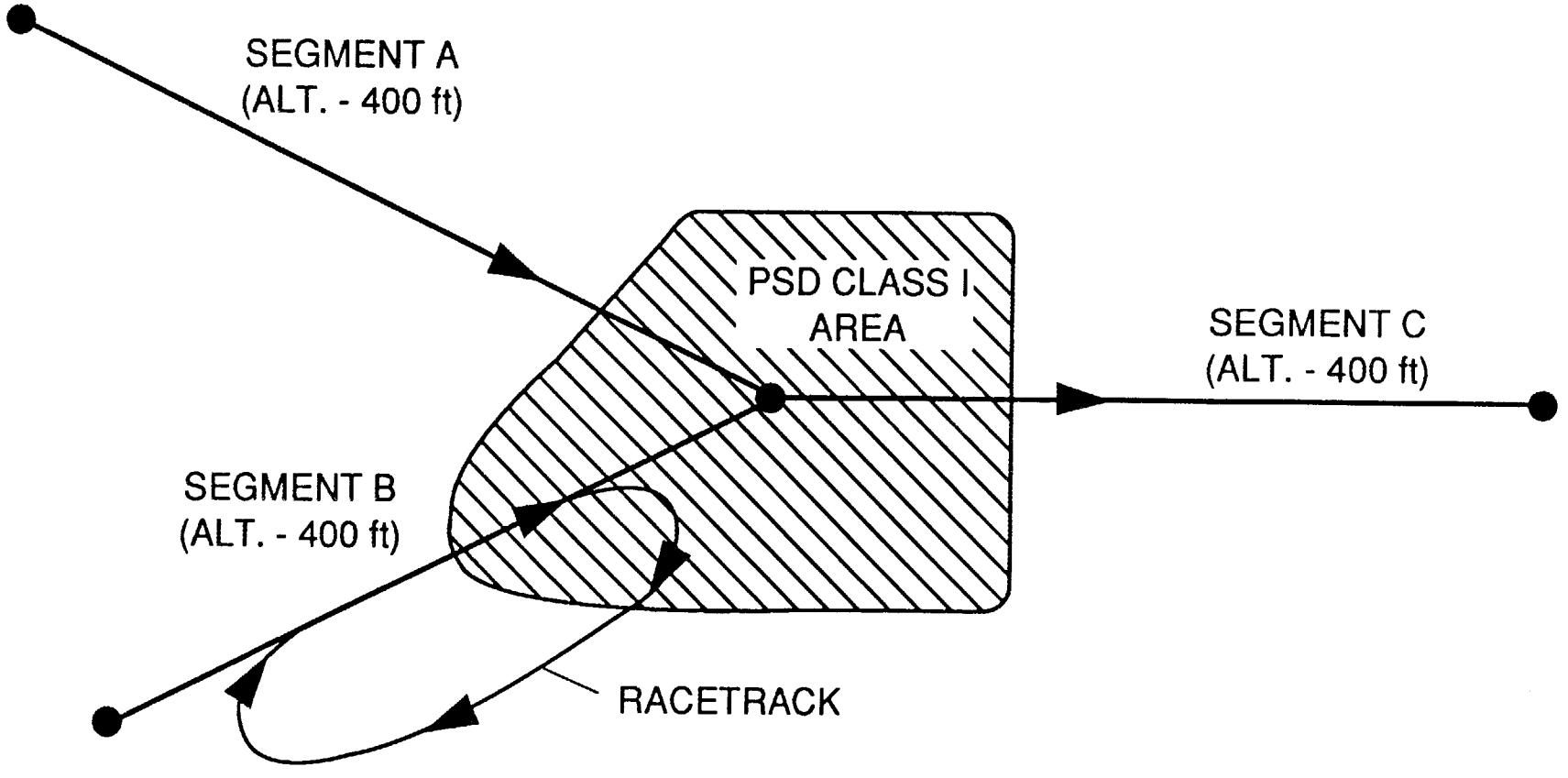

Fig. 10. Hypothetical military training route segments for Example 1.

The MAILS system is started by typing *run* at the DOS prompt and pressing *Enter*. After *Run MAILS Model* is selected from the main menu, the system prompts the user for the number of aircraft, run mode, pollutant (the user selects SO_2), and other data before displaying a menu of aircraft with SO_2 emissions data. The user then can scroll to one of the desired aircraft records and press *Esc* to select it. The required model input parameters for this aircraft are then displayed for editing. After entering or modifying the data as desired, the user presses *Enter* to write the data to a temporary file for model input. The system then redisplays the menu of aircraft, and the process is repeated until four aircraft records have been written to the temporary file. After the required data is entered for the fourth aircraft, the system prompts the user with the screen shown in Fig. 11 and asks if the data are correct. If the user response is affirmative, model execution begins. The MAILS model computes the maximum increases (increments) in 3-h, 24-h, and annual SO_2 concentrations and also the percentages of the allowable PSD Class I increments represented by these impacts. These values are then fed directly to the printer or to a user-named print file, depending on the user's preference as selected during the model input phase. Model output is also sent to a backup print file (filename = MODEL.PRT) when the option is chosen to send output directly to the printer.

The MAILS results shown in Fig. 12 indicate that the maximum 3-h, 24-h, and annual SO_2 concentrations are less than 5% of the allowable PSD Class I increments. Therefore, the impacts of the MTR segment on PSD Class I SO_2 increments are considered negligible, and no further analysis is required for SO_2. Additional model runs for NO_2 and PM-10 would complete the analysis of air-quality for the PSD Class I area.

4.3.2 Example 2

Figure 13 shows a hypothetical set of MTR segments, two of which cross twp separate PSD Class I areas. Table 6 shows the aircraft altitude and frequency data used for this example. The other necessary model input data for these aircraft were those contained in the emissions database.

The most efficient analytical approach would be to first attempt to determine by inspection if one of the Class I area segments would clearly cause a greater impact than the other. The worst-case segment could then be modeled, and if the predicted impacts were negligible (< 5% of any PSD Class I increment) for all pollutants, the other segment would not have to be modeled. In this case, segment *C* clearly has the greatest cumulative emissions density, and segment *A* has a lower minimum altitude. Therefore, it cannot be readily determined beforehand which segment would cause the greatest ground-level concentrations (i.e., both segments must be modeled).

The data-entry screens are not shown for this example because they will be basically the same as those in Example 1, except for data values. Only the output results for SO_2, which are shown in Figs. 14 and 15, are discussed for this example.

The MAILS results indicate that the incremental 3-h, 24-h, and annual SO_2 concentrations will be negligible (< 5%) with respect to the corresponding PSD Class I increments at both of the hypothetical PSD Class I areas shown in Fig. 13. Note that the predicted concentrations were somewhat greater for segment *A* than for segment *C*. Thus, the lower minimum altitude on segment *A* had a greater effect on predicted pollutant levels than did the greater emissions density (more flights) on segment *C*. Additional model runs for NO_2 and PM-10 for each of the Class I areas would complete the air-quality analysis.

Table 5. Aircraft input data for Example 1

Route segments	Aircraft	Minimum altitude (ft)	Maximum flight frequency 3-h	24-h	Annual
A	B52G	400			200
A	B52H	400			500
A	B1B	400			100
B	FB111	400			300/450[a]
B	B1B	400			100/150[a]
C	B52G	400	6	16	200
C	B52H	400			500
C	B1B	400			200
C	FB111	400			300

[a]The numerator denotes the total annual number of flights (sorties) on this MTR segment, but because half of the flights are expected to make a second pass on segment B via the *racetrack*, the total number of aircraft passes for segment B would be as shown in the denominator.

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Air Quality Modeling System SO2 Model Data Review Screen

Aircraft	Altitude (Ft.)	Mix Height	Airspeed (mph)	Emiss. Rate (lb/hr)	Frequency 1Hr	3Hr	8Hr	24H	Annl
B52G	400	5000	400	53.52		6		16	200
B52H	400	5000	400	49.92		0		0	500
B1B	400	5000	610	20.44		0		0	200
FB111	400	5000	550	11.42		0		0	300

Entries correct (Y/N) or Quit (Y/N/Q) ? Y

Fig. 11. Model Data-Review screen.

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```
MAILS - VERSION 1.1 (2/15/90): MULTIPLE AIRCRAFT INSTANTANEOUS LINE SOURCE MODEL

EXAMPLE 1                                                                *********

 Pollutant  :  SO2          No. of Aircraft (Types) :      4
 Avg. Period:  3-hour       Mixing Height           :   5000 ft.

Aircraft   Altitude   Airspeed  Emiss. Rate  Flight    3-hour  Conc.
           (ft)       (mph)     (lb/hr)      Freq.   (micrograms/m**3)
--------   --------   --------  -----------  ------  ----------------
  B52G       400        400        53.52        6          .2269
  B52H       400        400        49.92        0       0.00E+00
  B1B        400        610        20.44        0       0.00E+00
  FB111      400        550        11.42        0       0.00E+00
                                                       ----------------
                                Total 3-hour  conc. =       .2269

       The total 3-hour  conc. is     .9076 % of the PSD
   Class I 3-hour  increment for SO2 (    25 micrograms/m**3)

EXAMPLE 1                                                                *********

 Pollutant  :  SO2          No. of Aircraft (Types) :      4
 Avg. Period:  24-hour      Mixing Height           :   5000 ft.

Aircraft   Altitude   Airspeed  Emiss. Rate  Flight    24-hour Conc.
           (ft)       (mph)     (lb/hr)      Freq.   (micrograms/m**3)
--------   --------   --------  -----------  ------  ----------------
  B52G       400        400        53.52       16          .0378
  B52H       400        400        49.92        0       0.00E+00
  B1B        400        610        20.44        0       0.00E+00
  FB111      400        550        11.42        0       0.00E+00
                                                       ----------------
                                Total 24-hour conc. =       .0378

       The total 24-hour conc. is     .7563 % of the PSD
   Class I 24-hour increment for SO2 (     5 micrograms/m**3)

EXAMPLE 1                                                                *********

 Pollutant  :  SO2          No. of Aircraft (Types) :      4
 Avg. Period:  Annual       Mixing Height           :   5000 ft.

Aircraft   Altitude   Airspeed  Emiss. Rate  Flight    Annual  Conc.
           (ft)       (mph)     (lb/hr)      Freq.   (micrograms/m**3)
--------   --------   --------  -----------  ------  ----------------
  B52G       400        400        53.52      200          .0005
  B52H       400        400        49.92      500          .0012
  B1B        400        610        20.44      200          .0001
  FB111      400        550        11.42      300          .0001
                                                       ----------------
                                Total annual conc.  =       .0020

       The total annual conc. is     .0988 % of the PSD
   Class I annual increment for SO2 (     2 micrograms/m**3)
```

Fig. 12. MAILS SO_2 results for Example 1.

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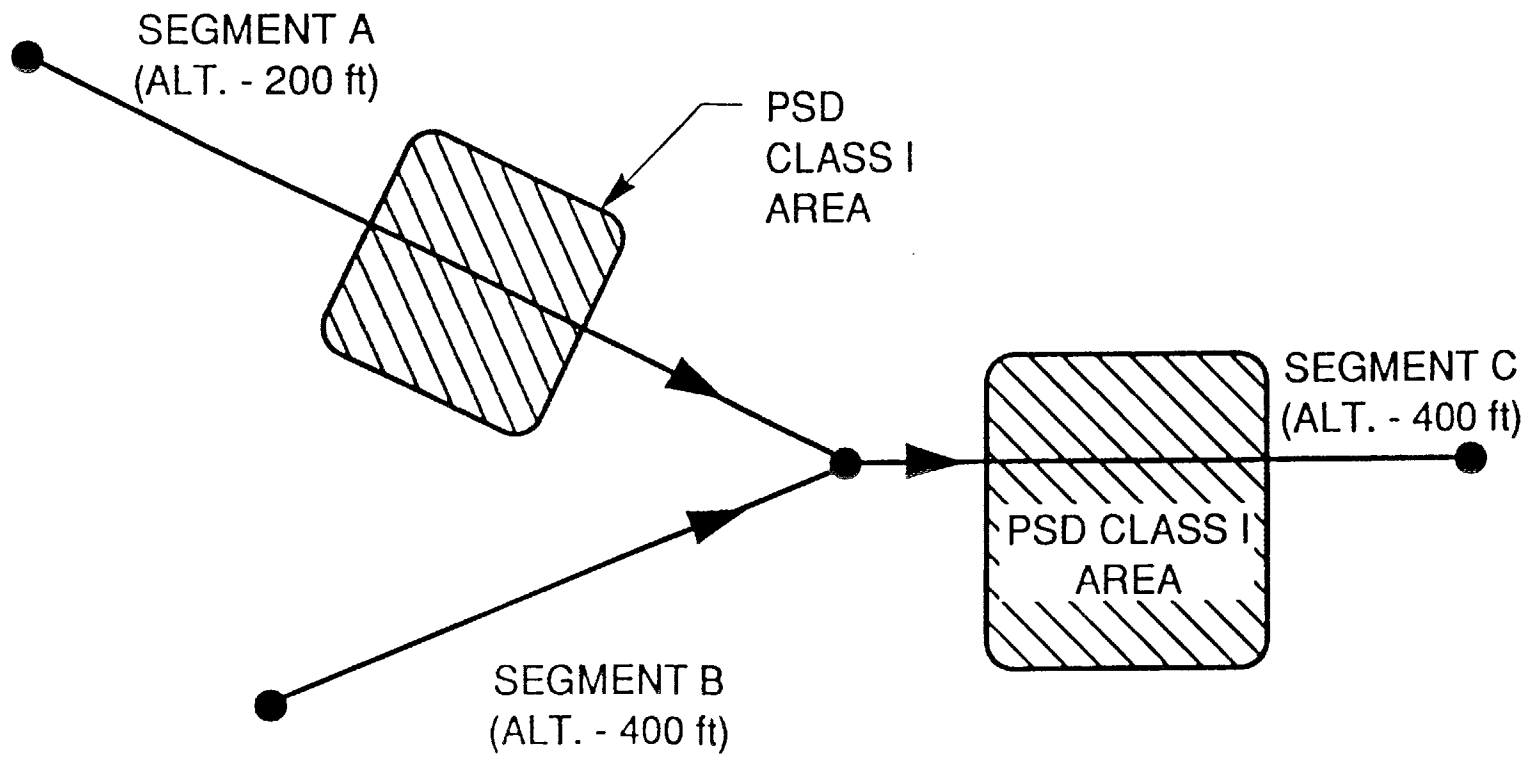

Fig. 13. Hypothetical military training route segments for Example 2.

Table 6. Aircraft input data for Example 2

Route segments[a]	Aircraft	Minimum altitude (ft)	Maximum flight frequency		
			3-h	24-h	Annual
A	A10	200			400
A	F4E	200	8	20	400
A	F16	200			400
B	F4E	400			800
					400
C	A10	400			1200
C	F4E	400	12	30	400
C	F16	400			

[a]See Fig. 13.

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```
MAILS - VERSION 1.1 (2/15/90): MULTIPLE AIRCRAFT INSTANTANEOUS LINE SOURCE MODEL

EXAMPLE 2, SEGMENT A                                                    *********

 Pollutant  :  SO2            No. of Aircraft (Types) :      3
 Avg. Period:  3-hour         Mixing Height           :   5000 ft.

Aircraft   Altitude   Airspeed  Emiss. Rate  Flight    3-hour  Conc.
            (ft)       (mph)     (lb/hr)    Freq.   (micrograms/m**3)
--------   --------   --------  -----------  ------  -----------------
  A10        200        405         1.84       0       0.00E+00
  F4E        200        550        14.00       8          .1692
  F16        200        550         5.11       0       0.00E+00
                                                      -----------------
                                Total 3-hour  conc. =       .1692

        The total 3-hour  conc. is    .6767 % of the PSD
   Class I 3-hour  increment for SO2 (    25 micrograms/m**3)

EXAMPLE 2, SEGMENT A                                                    *********

 Pollutant  :  SO2            No. of Aircraft (Types) :      3
 Avg. Period:  24-hour        Mixing Height           :   5000 ft.

Aircraft   Altitude   Airspeed  Emiss. Rate  Flight    24-hour Conc.
            (ft)       (mph)     (lb/hr)    Freq.   (micrograms/m**3)
--------   --------   --------  -----------  ------  -----------------
  A10        200        405         1.84       0       0.00E+00
  F4E        200        550        14.00      20          .0264
  F16        200        550         5.11       0       0.00E+00
                                                      -----------------
                                Total 24-hour conc. =       .0264

        The total 24-hour conc. is    .5286 % of the PSD
   Class I 24-hour increment for SO2 (     5 micrograms/m**3)

EXAMPLE 2, SEGMENT A                                                    *********

 Pollutant  :  SO2            No. of Aircraft (Types) :      3
 Avg. Period:  Annual         Mixing Height           :   5000 ft.

Aircraft   Altitude   Airspeed  Emiss. Rate  Flight    Annual  Conc.
            (ft)       (mph)     (lb/hr)    Freq.   (micrograms/m**3)
--------   --------   --------  -----------  ------  -----------------
  A10        200        405         1.84     400          .0001
  F4E        200        550        14.00     400          .0006
  F16        200        550         5.11     400          .0002
                                                      -----------------
                                Total annual conc.  =       .0009

        The total annual conc. is    .0447 % of the PSD
   Class I annual increment for SO2 (     2 micrograms/m**3)
```

Fig. 14. MAILS SO_2 results for Example 2, Segment *A*.

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```
MAILS - VERSION 1.1 (2/15/90): MULTIPLE AIRCRAFT INSTANTANEOUS LINE SOURCE MODEL

EXAMPLE 2, SEGMENT C                                                    *********

 Pollutant  :  SO2            No. of Aircraft (Types) :      3
 Avg. Period:  3-hour         Mixing Height           :   5000 ft.

Aircraft   Altitude   Airspeed  Emiss. Rate  Flight    3-hour  Conc.
            (ft)       (mph)      (lb/hr)    Freq.   (micrograms/m**3)
--------   --------   --------  ----------  ------  -----------------
  A10        400        405         1.84       0       0.00E+00
  F4E        400        550        14.00      12          .0863
  F16        400        550         5.11       0       0.00E+00
                                                     -----------------
                                Total 3-hour  conc. =       .0863

        The total 3-hour  conc. is    .3453 % of the PSD
    Class I 3-hour  increment for SO2 (   25 micrograms/m**3)

EXAMPLE 2, SEGMENT C                                                    *********

 Pollutant  :  SO2            No. of Aircraft (Types) :      3
 Avg. Period:  24-hour        Mixing Height           :   5000 ft.

Aircraft   Altitude   Airspeed  Emiss. Rate  Flight    24-hour Conc.
            (ft)       (mph)      (lb/hr)    Freq.   (micrograms/m**3)
--------   --------   --------  ----------  ------  -----------------
  A10        400        405         1.84       0       0.00E+00
  F4E        400        550        14.00      30          .0135
  F16        400        550         5.11       0       0.00E+00
                                                     -----------------
                                Total 24-hour conc. =       .0135

        The total 24-hour conc. is    .2698 % of the PSD
    Class I 24-hour increment for SO2 (    5 micrograms/m**3)

EXAMPLE 2, SEGMENT C                                                    *********

 Pollutant  :  SO2            No. of Aircraft (Types) :      3
 Avg. Period:  Annual         Mixing Height           :   5000 ft.

Aircraft   Altitude   Airspeed  Emiss. Rate  Flight    Annual  Conc.
            (ft)       (mph)      (lb/hr)    Freq.   (micrograms/m**3)
--------   --------   --------  ----------  ------  -----------------
  A10        400        405         1.84     400       3.52E-05
  F4E        400        550        14.00    1200          .0006
  F16        400        550         5.11     400       7.19E-05
                                                     -----------------
                                Total annual conc.  =       .0007

        The total annual conc. is    .0349 % of the PSD
    Class I annual increment for SO2 (    2 micrograms/m**3)
```

Fig. 15. MAILS SO_2 results for Example 2, Segment *C*.

5. CONCLUSIONS

This user's guide provides a detailed description of the interactive MAILS air-quality model and instructions for its use. MAILS is a simple screening model, providing estimates of worst-case concentrations for MTRs. The model incorporates an aircraft-pollutant emissions database to allow convenient user input for runs.

The intended application of the MAILS model is the prediction of ground-level pollutant concentrations resulting from low-flying (fewer than 3000 ft above ground level) military-aircraft operations along a prescribed route. Previous studies have demonstrated that air-quality impacts from low-flying military aircraft are (1) negligible with respect to NAAQS and PSD Class II air-quality increments and (2) potentially significant with respect to PSD Class I air-quality increments, which apply primarily to certain national parks and wilderness areas. Therefore, the instructions and example applications described in this report focus on the use of the MAILS model for analysis of air-quality impacts on PSD Class I areas.

6. REFERENCES

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APPENDIX A

National Ambient Air Quality Standards (NAAQS) and prevention of significant deterioration (PSD) increments[a]

Pollutant	Averaging time	NAAQS	PSD increments Class II	PSD increments Class I
Nitrogen dioxide	Annual	100	25	2.5
Sulfur dioxide	3-h	1,300[b]	512[b]	25[b]
	24-h	365[b]	91[b]	5[b]
	Annual	80	20	2
Particulate matter[c]	24-h	150[b]	30[b,d]	8[b,d]
	Annual	50	17[d]	4[d]
Carbon monoxide	1-h	40,000[b]		
	8-h	10,000[b]		
Ozone	1-h	235[e]		
Lead	Calendar quarter	1.5		

[a]All concentrations are in units of $\mu g/m^3$.
[b]Not to be exceeded more than once per year.
[c]Particulate matter less than 10 μm in diameter (PM-10).
[d]Listed PM-10 Class II and I increments were recently proposed, pending final rule promulgation.
[e]Not to be exceeded on more than 1 day per year.

APPENDIX B

PREVENTION OF SIGNIFICANT DETERIORATION (PSD) CLASS I AIR-QUALITY AREAS

Figure B-1 shows the PSD Class I areas that were designated under the Clean Air Act amendments of 1977. A listing of these areas by states is provided in Table B-1. An additional area, the Northern Cheyenne Indian Reservation in Montana, was redesignated later to PSD Class I status. More-detailed maps of particular PSD Class I areas can be obtained from the U.S. Department of Interior, Bureau of Land Management. The *state wilderness maps* available from this agency should provide sufficient resolution of parks and wilderness areas for those involved in the analysis of military training route air-quality impacts on PSD Class I areas.

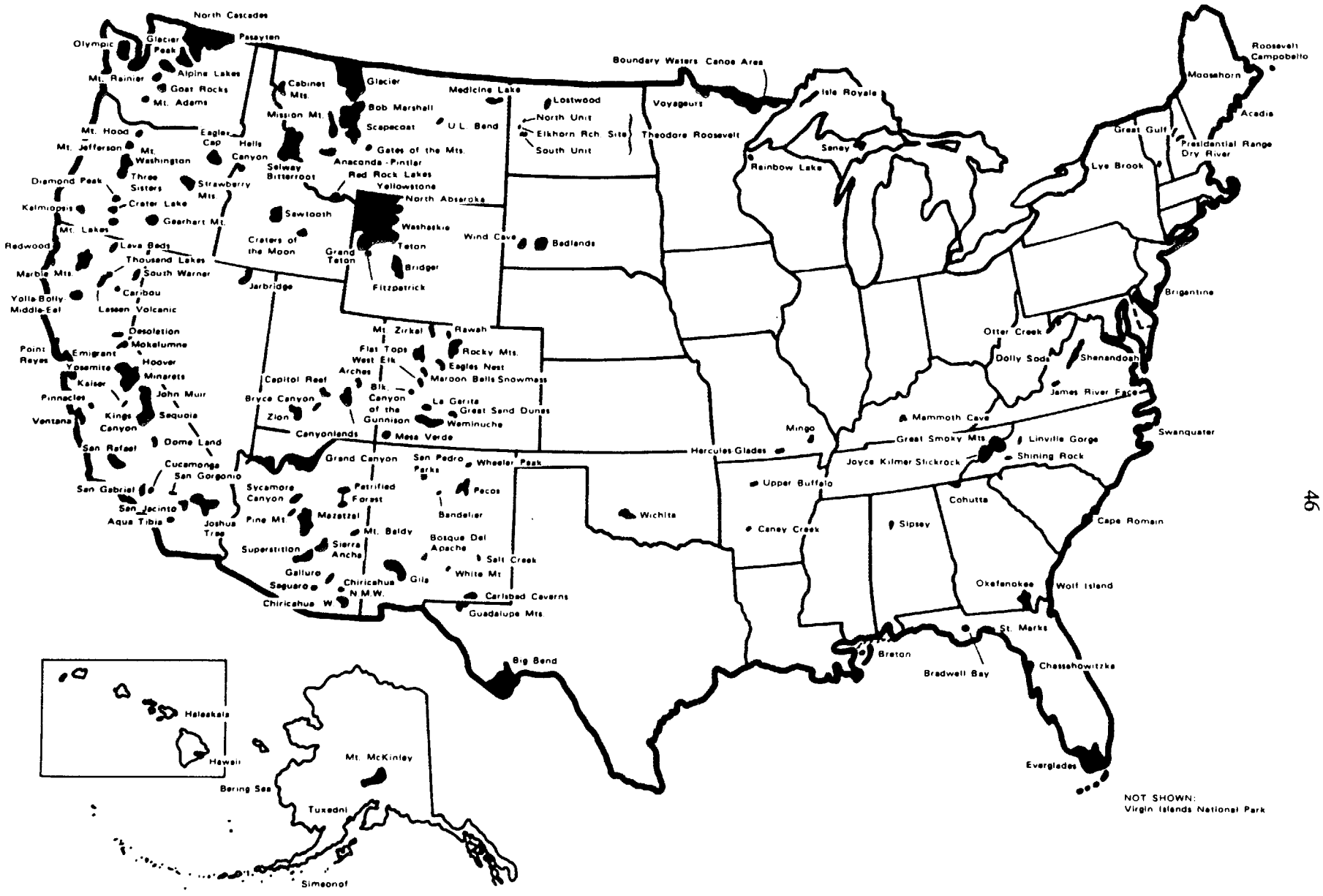

Fig. B-1. Prevention of significant deterioration Class I areas designated under the Clean Air Act Amendments of 1977.

Table B-1. Prevention of significant deterioration Class I areas designated by the Clean Air Act Amendments of 1977

Area names[a]	State	Acreage	Establishing public law	Federal land manager
Sipsey Wild.	AL	12,646	93-622	USDA-FS
Bering Sea Wild.	AK	41,113	91-622	USDI-FWS
Mount McKinley NP	AK	1,939,493	64-353	USDI-NPS
Simeonof Wild.	AK	25,141	94-557	USDA-FWS
Tuxedni Wild.	AK	6,402	91-504	USDI-FWS
Chiricahua National Monument Wild.	AZ	9,440	94-567	USDI-NPS
Chiricahua Wild	AZ	18,000	88-577	USDA-FS
Galiuro Wild.	AZ	52,717	88-577	USDA-FS
Grand Canyon NP	AZ	1,176,913	65-277	USDI-NPS
Mazatzal Wild.	AZ	205,137	88-577	USDA-FS
Mount Baldy Wild.	AZ	6,975	91-504	USDA-FS
Petrified Forest NP	AZ	93,493	85-358	USDI-NPS
Pine Mtn. Wild.	AZ	20,061	92-230	USDA-FS
Saguaro Wild.	AZ	71,400	94-567	USDI-NPS
Sierra Ancha Wild.	AZ	20,850	88-577	USDA-FS
Superstition Wild.	AZ	124,117	88-577	USDA-FS
Sycamore Canyon Wild.	AZ	47,757	92-241	USDA-FS
Caney Creek Wild.	AR	14,344	93-622	USDA-FS
Upper Buffalo Wild.	AR	9,912	93-622	USDA-FS
Agua Tibia Wild.	CA	15,934	93-632	USDA-FS
Caribou Wild.	CA	19,080	88-577	USDA-FS
Cucamonga Wild.	CA	9,022	88-577	USDA-FS
Desolation Wild.	CA	63,469	91-82	USDA-FS
Dome Land Wild.	CA	62,206	88-577	USDA-FS
Emigrant Wild.	CA	104,311	93-632	USDA-FS
Hoover Wild.	CA	47,916	88-577	USDA-FS
John Muir Wild.	CA	484,673	88-577	USDA-FS
Joshua Tree Wild.	CA	429,690	94-567	USDI-NPS
Kaiser Wild.	CA	22,500	94-577	USDA-FS
Kings Canyon NP	CA	459,994	76-424	USDI-NPS
Lassen Volcanic NP	CA	105,800	64-184	USDI-NPS
Lava Beds Wild.	CA	28,640	92-493	USDI-NPS
Marble Mtn. Wild.	CA	213,743	88-577	USDA-FS
Minarets Wild.	CA	109,484	88-577	USDA-FS
Mokelumne Wild.	CA	50,400	88-577	USDA-FS
Pinnacles Wild.	CA	12,952	94-567	USDI-NPS
Point Reyes Wild.	CA	25,370	94-544, 94-567	USDI-NPS
Redwood NP	CA	27,792	90-545	USDI-NPS
San Gabriel Wild.	CA	36,137	90-318	USDA-FS
San Gorgonio Wild.	CA	34,644	88-577	USDA-FS

Table B-1. (continued)

Area names[a]	State	Acreage	Establishing public law	Federal land manager
San Jacinto Wild.	CA	20,564	88-577	USDA-FS
San Rafael Wild.	CA	142,722	90-271	USDA-FS
Sequoia NP	CA	386,642	26 Stat. 478 (51st Cong.)	USDI-NPS
South Warner Wild.	CA	68,507	88-577	USDA-FS
Thousand Lakes Wild.	CA	15,695	88-577	USDA-FS
Ventana Wild.	CA	95,152	91-58	USDA-FS
Yolla-Bolly-Middle-Eel Wild.	CA	109,091	88-577	USDA-FS
Yosemite NP	CA	759,172	58-49	USDI-NPS
Black Canyon of the Gunnison Wild.	CO	11,180	94-567	USDI-NPS
Eagles Nest Wild.	CO	133,910	94-352	USDA-FS
Flat Tops Wild.	CO	235,230	94-146	USDA-FS
Great Sand Dunes Wild.	CO	33,450	94-567	USDI-NPS
La Garita Wild.	CO	48,486	88-577	USDA-FS
Maroon Bells–Snowmass Wild.	CO	71,060	88-577	USDA-FS
Mesa Verde NP	CO	51,488	59-353	USDI-NPS
Mt. Zirkel Wild.	CO	72,472	88-577	USDA-FS
Rawah Wild.	CO	26,674	88-577	USDA-FS
Rocky Mountain NP	CO	263,138	63-238	USDI-NPS
Weminuche Wild.	CO	400,907	93-632	USDA-FS
West Elk Wild.	CO	61,412	88-577	USDA-FS
Bradwell Bay Wild.	FL	23,432	93-622	USDA-FS
Chassahowitzka Wild.	FL	23,360	94-557	USDI-FWS
Everglades NP	FL	1,397,429	73-267	USDI-NPS
St. Marks Wild.	FL	17,745	93-632	USDI-FWS
Cohotta Wild.	GA	33,776	93-622	USDA-FS
Okefenokee Wild.	GA	343,850	93-429	USDI-FWS
Wolf Island Wild.	GA	5,126	93-632	USDI-FWS
Haleakala NP	HI	27,208	86-744	USDI-NPS
Hawaii Volcanoes	HI	217,029	64-171	USDI-NPS
Craters of the Moon Wild.	ID	43,243	91-504	USDI-NPS
Hells Canyon Wild.[b]	ID	83,800	94-199	USDA-FS
Sawtooth Wild.	ID	216,383	92-400	USDA-FS
Selway-Bitterroot Wild.[c]	ID	988,770	88-577	USDA-FS
Yellowstone NP[d]	ID	31,488	17 Stat. 32 (42nd Cong.)	USDI-NPS
Mammoth Cave NP	KY	51,303	69-283	USDI-NPS
Breton Wild.	LA	5,000+	93-632	USDI-FWS

Table B-1. (continued)

Area names[a]	State	Acreage	Establishing public law	Federal land manager
Acadia NP	ME	37,503	65-278	USDI-NPS
Moosehorn Wild.	ME	7,501		USDI-FWS
(Edmunds Unit)		(2,782)	91-504	
(Baring Unit)		(4,719)	93-632	
Isle Royale NP	MI	542,428	71-835	USDI-NPS
Seney Wild.	MI	25,150	91-504	USDI-FWS
Boundary Waters Canoe Area Wild.	MN	747,840	88-577	USDA-FS
Voyageurs NP	MN	114,964	99-261	USDI-NPS
Hercules-Glades Wild.	MO	12,315	94-557	USDA-FS
Mingo Wild.	MO	8,000	94-557	USDI-FWS
Anaconda-Pintlar Wild.	MT	157,803	88-577	USDA-FS
Bob Marshall Wild.	MT	950,000	88-577	USDA-FS
Cabinet Mtns. Wild.	MT	94,272	88-577	USDA-FS
Gates of the Mtn. Wild.	MT	28,562	88-577	USDA-FS
Glacier NP	MT	1,012,599	61-171	USDI-NPS
Medicine Lake Wild.	MT	11,366	94-557	USDI-FWS
Mission Mtn. Wild.	MT	73,877	93-632	USDA-FS
Red Rock Lakes	MT	32,350	94-557	USDI-FWS
Wild.Scapegoat Wild.	MT	239,295	92-395	USDA-FS
Selway-Bitterroot Wild.[c]	MT	251,930	88-577	USDA-FS
U.L. Bend Wild.	MT	20,890	94-557	USDI-FWS
Yellowstone NP[d]	MT	167,624	17 Stat. 32 (42nd Cong.)	USDI-NPS
Jarbridge Wild.	NV	64,667	88-577	USDA-FS
Great Gulf Wild.	NH	5,552	88-577	USDA-FS
Presidential Range-Dry River Wild.	NH	20,000	93-622	USDA-FS
Brigantine Wild.	NJ	6,603	93-632	USDI-FWS
Bandelier Wild.	NM	23,267	94-567	USDI-NPS
Bosque del Apache Wild.	NM	30,850	93-632	USDI-FWS
Carlsbad Caverns NP	NM	46,435	71-216	USDI-NPS
Gila Wild.	NM	433,690	88-577	USDA-FS
Pecos Wild.	NM	167,416	88-577	USDA-FS
Salt Creek Wild.	NM	8,500	91-504	USDI-FWS
San Pedro Parks Wild.	NM	41,132	88-577	USDA-FS
Wheeler Peak Wild.	NM	6,027	88-577	USDA-FS
White Mtn. Wild.	NM	31,171	88-577	USDA-FS
Great Smoky Mtns. NP[e]	NC	273,551	69-268	USDI-NPS
Joyce Kilmer–Slickrock Wild.[f]	NC	10,201	93-622	USDA-FS

Table B-1. (continued)

Area names[a]	State	Acreage	Establishing public law	Federal land manager
Linville Gorge Wild.	NC	7,575	88-577	USDA-FS
Shining Rock Wild.	NC	13,350	88-577	USDA-FS
Swanguarter Wild.	NC	9,000	94-557	USDI-FWS
Lostwood Wild.	ND	5,557	93-632	USDI-FWS
Theodore Roosevelt NMP	ND	69,675	80-38	USDI-NPS
Wichita Mtns. Wild.	OK	8,900	91-504	USDI-FWS
Crater Lake NP	OR	160,290	57-121	USDI-NPS
Diamond Peak Wild.	OR	36,637	88-577	USDA-FS
Eagle Cap Wild.	OR	293,476	88-577	USDA-FS
Gearhart Mtn. Wild.	OR	18,709	88-577	USDA-FS
Hells Canyon Wild.[b]	OR	108,900	94-199	USDA-FS
Kalmiopsis Wild.	OR	76,900	88-577	USDA-FS
Mtn. Lakes Wild.	OR	23,071	88-577	USDA-FS
Mt. Hood Wild.	OR	14,160	88-577	USDA-FS
Mt. Jefferson Wild.	OR	100,208	90-548	USDA-FS
Mt. Washington Wild.	OR	46,116	88-577	USDA-FS
Strawberry Mtn. Wild.	OR	33,003	88-577	USDA-FS
Three Sisters Wild.	OR	199,902	88-577	USDA-FS
Cape Romain Wild.	SC	28,000	93-632	USDI-FWS
Badlands Wild.	SD	64,250	94-567	USDI-NPS
Wind Cave NP	SD	28,060	57-16	USDI-NPS
Great Smoky Mtns. NP[e]	TN	241,207	69-268	USDI-NPS
Joyce Kilmer–Slickrock Wild.[f]	TN	3,832	93-622	USDA-FS
Big Bend NP	TX	708,118	74-157	USDI-NPS
Guadalupe Mtns. NP	TX	76,292	89-667	USDI-NPS
Arches NP	UT	65,098	92-155	USDI-NPS
Bryce Canyon NP	UT	35,832	68-277	USDI-NPS
Canyonlands NP	UT	337,570	88-590	USDI-NPS
Capitol Reef NP	UT	221,896	92-507	USDI-NPS
Zion NP	UT	142,462	68-83	USDI-NPS
Lyle Brook Wild.	VT	12,430	93-622	USDAFS
Virgin Islands NP	VI	12,295	84-925	USDI-NPS
James River Face Wild.	VA	8,703	93-622	USDA-FS
Shenandoah NP	VA	190,535	69-268	USDI-NPS
Alpine Lakes Wild.	WA	303,508	94-357	USDA-FS
Glacier Peak Wild.	WA	464,258	88-577	USDA-FS
Goat Rocks Wild.	WA	82,680	88-577	USDA-FS
Mount Adams Wild.	WA	32,356	88-577	USDA-FS
Mount Rainier NP	WA	235,239	30 Stat. 993 (55th Cong.)	USDI-NPS
North Cascades NP	WA	503,277	90-554	USDI-NPS

Table B-1. (continued)

Area names[a]	State	Acreage	Establishing public law	Federal land manager
Olympic NP	WA	892,578	75-778	USDI-NPS
Pasayten Wild.	WA	505,524	90-554	USDA-FS
Dolly Sods Wild.	WV	10,215	93-622	USDA-FS
Otter Creek Wild.	WV	20,000	93-622	USDA-FS
Rainbow Lake Wild.	WI	6,388	93-622	USDA-FS
Bridger Wild.	WY	392,160	88-577	USDA-FS
Fitzpatrick Wild.	WY	191,103	94-567	USDA-FS
Grand Teton NP	WY	305,504	81-787	USDI-NPS
North Absaroka Wild.	WY	351,104	88-577	USDA-FS
Teton Wild.	WY	557,311	88-577	USDA-FS
Washakie Wild.	WY	686,584	92-476	USDA-FS
Yellowstone NP[d]	WY	2,020,625	17 Stat. 32 (42nd Cong.)	USDI-NPS
Roosevelt Campobello International Park[g]	New Brunswick, Canada	2,721	88-363	

[a]Wilderness is abbreviated as Wild., National Park and NP, and National Memorial Park as NMP.

[b]Hells Canyon Wilderness, 193,840 acres overall, of which 108,900 acres are in Oregon and 83,800 acres are in Idaho.

[c]Selway Bitterroot Wilderness, 1,240,618 acres overall, of which 988,770 acres are in Idaho and 25,930 acres are in Montana.

[d]Yellowstone National Park, 2,219,737 acres overall, of which 2,020,625 acres are in Wyoming, 167,624 acres are in Montana, and 31,488 acres are in Idaho.

[e]Great Smoky Mountains National Park, 514,577 acres overall, of which 273,551 acres are in North Carolina and 241,207 acres are in Tennessee.

[f]Joyce Kilmer–Slickrock Wilderness, 14,033 acres overall, of which 10,201 acres are in North Carolina and 3,832 acres are in Tennessee.

[g]Section 162(a) designates all international parks as mandatory Class I areas. This designation indicates Congressional intent to prevent visibility impairment from U.S. air-pollution sources.

APPENDIX C

MAILS DISPERSION MODEL FORTRAN CODE

ORNL-DWG 90-14741

```
$INCLUDE: 'FOREXEC.INC'
C   MULTIPLE AIRCRAFT INSTANTANEOUS LINE SOURCE (MAILS) MODEL
C          VERSION: 1.1, DATED 2/15/90
C
C          AUTHORS:  EDWARD LIEBSCH, RESEARCH ASSOCIATE,
C                        (615-574-2702)
C                    R.D. SHARP, COMPUTING SPECIALIST II
C                        (615-576-2308)
C
C                    OAK RIDGE NATIONAL LABORATORY
C                    OPERATED BY MARTIN MARIETTA ENERGY SYSTEMS, INC.
C                    P.O. BOX 2008
C                    OAK RIDGE, TN. 37831
C
C
      CHARACTER*6 AIRC
      DIMENSION ISTAB(49),WS(49),ARR(49),SC(6),SD(6)
      DIMENSION AIRC(16),AS(16),QPRIME(16),RHT(16),IFR(5,16),CMAX(16)
      CHARACTER*70 TITLE
      CHARACTER*4 POLU
      CHARACTER*1 CHAR,STAND,PRDEST
      CHARACTER*12 FNAME
C
C
      DATA ISTAB / 7*1,9*2,9*3,14*4,5*5,5*6 /
      DATA WS / 0.5,0.8,1.0,1.5,2.0,2.5,3.0,0.5,0.8,1.0,1.5,2.0,2.5,3.0,
     14.0,5.0,2.0,2.5,3.0,4.0,5.0,7.0,10.0,12.0,15.0,0.5,0.8,1.0,1.5,2.0
     2,2.5,3.,4.,5.,7.,10.,12.,15.,20.,2.,2.5,3.,4.,5.,2.,2.5,3.,4.,5. /
      DATA SC,SD / 24.1667,18.333,12.5,8.333,6.25,4.1667,2.5334,1.8096,
     1 1.0857,.72382,.54287,.36191 /
C
      OPEN (UNIT=8,FILE = 'SAILS.OUT')
      OPEN(UNIT=1,FILE='MODEL.DAT')
      OPEN(UNIT=2,FILE='TITLE.DAT')
C
C   *************  DATA FILE TITLE.DAT CONTAINS A HEADER RECORD (A70) **
      READ(2,801) TITLE
C   ******************************************************************
C
C   ************** INPUT DATA (MODEL.DAT) ******************************
C     AIRC(i)    = AIRCRAFT i IDENTIFIER  (LE 6 CHARACTERS)
C     AS(i)      = THE AIRSPEED OF AIRCRAFT i (MPH)
C     QPRIME(i)  = THE RELEASE RATE OF POLLUTANT (LB/HR) FROM AIRCRAFT i
C     RHT(i)     = THE RELEASE HEIGHT (FT) OF POLLUTANT FROM AIRCRAFT i
C     AMH        = THE SURFACE MIXING (INVERSION) HEIGHT (FT)
C         THE INVERSION HEIGHT MUST BE GREATER THAN THE RELEASE HEIGHT
C         OR THE GROUND-LEVEL CONCENTRATION IS ASSUMED TO BE NEGLIGIBLE.
C         PROGRAM STOPS WITH CODE 1111 IF A VALUE LESS THAN OR EQUAL TO
C         THE RELEASE HEIGHT HAS BEEN ENTERED.
C     IFR(k,i)   = FREQUENCY OF FLIGHTS FOR AIRCRAFT i FOR TIME PERIOD k
C                  k=1(1-HR), k=2(3-HR), k=3(8-HR), k=4(24-HR), k=5(AN.)
C     POLU       = POLLUTANT NAME: SO2 ,NO2 ,PART, OR CO (4 CHARACTERS)
C     STAND      = STANDARDS RUN FLAG: S MEANS TO COMPARE CONCENTRATIONS
C                      AGAINST STANDARD PSD (NAAQS FOR 1,8-HR) INCREMENTS
C     PRDEST     = FLAG FOR PRINT DESTINATION: P MEANS TO WRITE THE CONC.
C                      TABLE TO THE PRINTER, AND TO FILE MODEL.PRT
C     PRDEST     =                                F MEANS TO WRITE THE CONC.
C                      TABLE TO FILE FNAME (SEE NEXT VARIABLE DEFINITION)
C     FNAME      = FILE NAME (LE 12 CHARACTERS) TO WHICH THE CONC. TABLE
C                      IS WRITTEN IF PRDEST=F
```

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```
C     ******************************************************************
C
        I=0
      1 I=I+1
        READ(1,802,END=15)AIRC(I),AS(I),QPRIME(I),RHT(I),AMH,(IFR(K,I),
     1      K=1,5),POLU,STAND,PRDEST,FNAME
        IF(RHT(I).GE.AMH)THEN
         WRITE(*,803)RHT(I),AMH,I
         STOP 1111
        END IF
        IF(I.EQ.1)THEN
         AMHFT=AMH
         IF(PRDEST.EQ.'F')THEN
          OPEN(UNIT=9,FILE=FNAME)
          WRITE(*,'('' Results from MAILS are written to file:'',
     1    2X,A12,/)')FNAME
         ELSE
          OPEN(UNIT=9,FILE='MODEL.PRT')
          WRITE(*,'('' Results from MAILS are written to file:'',
     1    2X,''MODEL.PRT'',/)')
         END IF
        END IF
        GO TO 1
     15 NUMAC=I-1
        WRITE(8,804)
        DO 310 IA=1,NUMAC
        IF(IA.EQ.1)THEN
         WRITE(8,805) TITLE
        ELSE
         WRITE(8,806)CHAR(12),TITLE
        END IF
        WRITE(8,807) AIRC(IA),RHT(IA),AMHFT,QPRIME(IA),AS(IA)
        WRITE(*,808)AIRC(IA)
C     SPECIFY PORTION OF LINE SOURCE TO BE MODELED AS A DISCRETE PUFF
C     IN UNITS OF METERS.
        PL = 100.
C     CONVERT AIRCRAFT AIRSPEED FROM MILES/HR. TO METERS/SEC.
        ASM = AS(IA)*0.447
C     CONVERT RELEASE HEIGHT AND MIXING HEIGHT FROM FEET TO METERS
        RHT(IA) = RHT(IA)*0.3048
        AMH = AMHFT*0.3048
        AMHI = 1.0/AMH
C     CONVERT EMISSION RATE FROM LB/HR TO GRAMS/SEC
        QPRIME(IA) = QPRIME(IA)*0.126
C     COMPUTE THE MASS OF ONE PUFF IN GRAMS
        Q = QPRIME(IA)*PL/ASM
C     BEGIN LOOP OVER ALL STABILITY/WIND SPEED COMBINATIONS
        DO 200 I=1,49
C     COMPUTE THE NUMBER OF PUFFS WHICH PASS A CENTERLINE RECEPTOR
C     IN A ONE-HOUR PERIOD
        NPUFF = WS(I)*3600./PL + 0.5
        UBARI = 1.0/WS(I)
        X = 0.0
        SPSI = 0.0
        IST = ISTAB(I)
C     BEGIN LOOP OVER PUFFS
        DO 100 J=1,NPUFF
        PX = J - 0.5
        X = PL*PX
        XK = .001*X
```

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```
C   COMPUTE SIGMA-Y
      TH = .017453293*(SC(IST)-SD(IST)*ALOG(XK))
      SIGY = 465.11628*XK*TAN(TH)
      SIGYI = 1.0/SIGY
C   CALL SUBROUTINE TO COMPUTE SIGMA-Z
      CALL SIGMAZ(XK,SZ,IST)
      SIGZI = 1.0/SZ
C   CHECK IF SIGMA-Z IS LARGE COMPARED TO MIXING HEIGHT
C   IF SO, ASSUME UNIFORM VERTICAL MIXING
C
      IF(SZ .GE. 1.6*AMH) GOTO 50
C   CALCULATE VERTICAL TERM (V)
      V = 0.0
      A2 = 0.0
   40 VL = V
      A2 = A2 + 2.0
      HMA2 = A2*AMH
      A3 = (HMA2-RHT(IA))*SIGZI
      A4 = (HMA2+RHT(IA))*SIGZI
      A3  = -.5*A3*A3
      A4 = -.5*A4*A4
      A5 = 0.0
      IF(A3 .GT. -38.) A5 = EXP(A3)
      A6 = 0.0
      IF(A4 .GT. -38.) A6 = EXP(A4)
      V = V + A5 + A6
      IF(ABS(V-VL) .GT. 1.E-8) GOTO 40
      A2 = -.5*RHT(IA)*RHT(IA)*SIGZI*SIGZI
      IF(A2 .GT. -38.) V = EXP(A2) + V
C   EQUATION FOR TOTAL EXPOSURE FROM AN INSTANTANEOUS PUFF RELEASE
      PSI = .318309886*Q*SIGYI*SIGZI*UBARI*V
      GOTO 90
C   EQUATION FOR TOTAL EXPOSURE FROM AN INSTANTANEOUS PUFF RELEASE WITH
C   UNIFORM VERTICAL MIXING
   50 PSI = Q*SIGYI*AMHI*UBARI*.39894228
C
C   SUM EXPOSURE FOR PUFF AND GET ANOTHER PUFF
   90 SPSI = SPSI + PSI
  100 CONTINUE
C
C   CONVERT ONE-HOUR EXPOSURE TO A ONE-HOUR CONCENTRATION
      CHI = SPSI/3600.0
      ARR(I) = CHI
  200 CONTINUE
C
C  WRITE OUTPUT TO FILE
      WRITE(8,809)
      ISTOLD = 1
      DO 300 I=1,49
      IF(ISTAB(I) .NE. ISTOLD) WRITE(8,810)
      WRITE(8,811) ISTAB(I),WS(I),ARR(I)
      CMAX(IA)=AMAX1(CMAX(IA),ARR(I))
      ISTOLD = ISTAB(I)
  300 CONTINUE
  310 CONTINUE
      CALL OUTPUT(AIRC,AS,QPRIME,RHT,AMHFT,IFR,CMAX,NUMAC,POLU,STAND,
     1            PRDEST,TITLE)
      STOP
C
C
```

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```
  801 FORMAT(A70)
  802 FORMAT(A6,F3.0,F8.0,F5.0,F5.0,4I3,I4,A4,A1,A1,A12)
  803  FORMAT(' The specified RELEASE HEIGHT ',F6.0,' is higher than the
     1 MIXING HEIGHT ',F7.0,/,'       for AIRCRAFT #',I3)
  804 FORMAT(25X,'MAILS - VERSION 1.1 (2/15/90)',/,25X,'MULTIPLE AIRCRAF
     1T INSTANTANEOUS',/,25X,'LINE SOURCE MODEL',///)
  805 FORMAT(32X,'**** TITLE ****',//,A70,//)
  806 FORMAT(A1,32X,'**** TITLE ****',//,A70,//)
  807 FORMAT(' INPUT DATA FOR AIRCRAFT ',A6,
     <       /' ----------',14X,'------',/,' RELEASE HEIGHT    =',F10.3
     1,' FEET',/,' INVERSION HEIGHT  =',F10.3,' FEET',/,' EMISSION RATE
     2    =',F10.3,' LB/HR',/,' AIRCRAFT AIRSPEED =',F10.3,' MILES/HR'//
     3/)
  808 FORMAT(' EXECUTION CONTINUING..... FOR AIRCRAFT ',A6)
  809 FORMAT(11X,'STABILITY',6X,'WIND SPEED',5X,'ONE-HR. CONC.',/,27X,'(
     1M/SEC.)',6X,'(GRAMS/M**3)')
  810 FORMAT(' ')
  811 FORMAT(14X,I2,11X,F6.2,8X,E11.4)
      END
C
C   SUBROUTINE SIGMAZ CALCULATES THE VERTICAL STANDARD DEVIATION OF
C   THE PUFF CONCENTRATION DISTRIBUTION.  THE COEFFICIENTS WERE TAKEN
C   FROM THE EPA ISCST MODEL (DATED 88207).
C
      SUBROUTINE SIGMAZ(X,SZ,IST)
      DIMENSION SASIGZ(38),SBSIGZ(38),X1(10,6),INDSGZ(6)
      DATA SASIGZ / 122.8,
     1              158.08,170.22,179.52,217.41,258.89,346.75,2*453.85,
     2 90.673,98.483,109.3,61.141,34.459,32.093,32.093,33.504,36.65,
     3  44.053,24.26,
     4        23.331,21.628,21.628,22.534,24.703,26.97,35.42,47.61,
     5 15.209,14.457,13.953,13.953,14.823,16.187,17.836,22.651,27.074,
     6 34.219 /
      DATA SBSIGZ /.9447,
     X              1.0542,1.0932,1.1262,1.2644,1.4094,1.7283,2*2.1166,
     1 .93198,.98332,1.0971,.91465,.86974,.81066,.64403,.60486,.56589,
     X  .51179,.8366,
     2        .81956,.75660,.63077,.57154,.50527,.46713,.37615,.29592,
     3 .81558,.78407,.68465,.63227,.54503,.46490,.41507,.32681,.27436,
     4 .21716 /
      DATA INDSGZ /0,9,12,13,19,28/
      DATA X1 /.1,.15,.2,.25,.3,.4,.5,3.11,1.E20,0.,  .2,.4,1.E20,7*0.,
     1 1.E20,9*0.,  .3,1.,3.,10.,30.,1.E20,4*0.,  .1,.3,1.,2.,4.,10.,
     2 20.,40.,1.E20,0.,  .2,.7,1.,2.,3.,7.,15.,30.,60.,1.E20/
C
      I = 1
      IF(IST .EQ. 3) GOTO 20
   10 IF(X-X1(I,IST) .LE. 0.0) GOTO 20
      I = I + 1
      GOTO 10
   20 INDX1 = INDSGZ(IST) + I
      SZ = SASIGZ(INDX1)*X**SBSIGZ(INDX1)
      SZ = AMIN1(SZ,5000.)
      RETURN
      END
      SUBROUTINE OUTPUT(AIRC,AS,QPRIME,RHT,AMH,IFR,CMAX,NUMAC,POLU,
     1                  STAND,PRDEST,TITLE)
      INTEGER*2 SYSTEM
      CHARACTER*70 TITLE
      CHARACTER ANS
```

ORNL-DWG 90-14738

```
      CHARACTER*6 AIRC
      CHARACTER*7 AVT(5)
      CHARACTER STAND,CHAR,PRDEST
      CHARACTER*4 POLU
      DIMENSION AIRC(16),AS(16),QPRIME(16),RHT(16),IFR(5,16),CMAX(16)
      DIMENSION PSD(3,4),KNTA(4),ITM(3,4),DIV(5),SFACT(5),NTP(5)
      DATA AVT/'1-hour ','3-hour ','8-hour ','24-hour','Annual '/
C     PSD(IT,IP) = PSD CLASS 1 INCREMENTS (micrograms/m**3)
C       IP=1 FOR NO,IP=2 FOR SO2, IP=3 FOR PART, IP=4 FOR CO
C            IT=1 FOR 1-HR, IT=2 FOR 3-HR, IT=3 FOR 8-HR, IT=4 FOR 24-HR
C        AND IT=5 FOR Annual
C       NOTE: FOR CO, PSD(1,4)= NAAQS 1-HR STANDARD,
C                     PSD(2,4)= NAAQS 8-HR STANDARD
C        -999. MEANS NO VALUE ASSIGNED (NA)
      DATA PSD/2.5,-999.,-999.,  25.,5.,2.,  8.,4.,-999.,
     1         40000.,10000.,-999./
      DATA KNTA/1,3,2,2/
      DATA ITM/5,0,0, 2,4,5, 4,5,0, 1,3,0/
      DATA NTP/5*0/
      DATA SFACT/1.0,0.5,0.33,0.25,0.1/
      DATA DIV/1.0,3.0,8.0,24.0,8760.0/
      WRITE(9,800)
      IF(POLU.EQ.'NO2 ')IP=1
      IF(POLU.EQ.'SO2 ')IP=2
      IF(POLU.EQ.'PART')IP=3
      IF(POLU.EQ.'CO  ')IP=4
      IAMH=IFIX(AMH+.5)
      IF(STAND.EQ.'S')THEN
       NUMT=KNTA(IP)
       NLTAB=15
      ELSE
       NUMT=5
       NLTAB=12
      END IF
        DO 5 NTAB=1,NUMT
        IF(NTAB.EQ.1)CALL TABLEC(NUMT,NLTAB,NUMAC,NTP)
        IF(NTP(NTAB).EQ.1.AND.NTAB.NE.1)THEN
         WRITE(9,8001)CHAR(12),TITLE
        ELSE
         WRITE(9,801)TITLE
        END IF
        WRITE(9,802)POLU,NUMAC
        IF(STAND.EQ.'S')THEN
         K=ITM(NTAB,IP)
        ELSE
         K=NTAB
        END IF
        WRITE(9,803)AVT(K),IAMH
        WRITE(9,804)AVT(K)
        WRITE(9,805)
        WRITE(9,806)
        CT=0.0
        DO 10 IA=1,NUMAC
C       TO PRINT PARAMETERS AS INTEGERS
        IRHT=IFIX(RHT(IA)/.3048+.5)
        IAS=IFIX(AS(IA)+.5)
        QP=QPRIME(IA)/.126
C       CONCENTRATION UNIT OF C IS MICROGRAMS
        C=((CMAX(IA)*FLOAT(IFR(K,IA)))/DIV(K))*SFACT(K)*1.0E+6
        CT=CT+C
```

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```
      IF(C.GE.1.0E-4)THEN
       WRITE(9,807)AIRC(IA),IRHT,IAS,QP,IFR(K,IA),C
      ELSE
       WRITE(9,808)AIRC(IA),IRHT,IAS,QP,IFR(K,IA),C
      END IF
 10   CONTINUE
     WRITE(9,809)
     IF(CT.GE.1.0E-4)THEN
      IF(AVT(K).NE.'Annual')WRITE(9,810)AVT(K),CT
      IF(AVT(K).EQ.'Annual')WRITE(9,811)CT
     ELSE
      IF(AVT(K).NE.'Annual')WRITE(9,812)AVT(K),CT
      IF(AVT(K).EQ.'Annual')WRITE(9,813)CT
     END IF
     IF(STAND.EQ.'S')THEN
      PERC=CT/PSD(NTAB,IP)*100.
      IPERC=IFIX(PSD(NTAB,IP))
      IF(PERC.GE.0.01)THEN
       IF(AVT(K).NE.'Annual')WRITE(9,814)AVT(K),PERC,AVT(K),POLU,IPERC
       IF(AVT(K).EQ.'Annual')WRITE(9,816)PERC,POLU,IPERC
      ELSE
       IF(AVT(K).NE.'Annual')WRITE(9,815)AVT(K),PERC,AVT(K),POLU,IPERC
       IF(AVT(K).EQ.'Annual')WRITE(9,817)PERC,POLU,IPERC
      END IF
     END IF
  5 CONTINUE
800 FORMAT('MAILS - VERSION 1.1 (2/15/90): MULTIPLE AIRCRAFT INSTANTAN
   1EOUS LINE SOURCE MODEL')
801   FORMAT(///,A70,' *********',/)
802   FORMAT(1X,'Pollutant  :  ',A4,T30,'No. of Aircraft (Types) :  ',
   1   I5)
803   FORMAT(1X,'Avg. Period:  ',A7,T30,'Mixing Height          :  ',
   1  I5,' ft.',/)
804 FORMAT('Aircraft',3X,'Altitude',3X,'Airspeed',2X,'Emiss. Rate',2X,
   1        'Flight',4X,A7,' Conc.')
805 FORMAT(T13,'(ft)',T24,'(mph)',T35,'(lb/hr)',T46,'Freq.',T59,
   1            'Conc.',T54,'(micrograms/m**3)')
806   FORMAT('--------',T12,'--------',T23,'--------',T33,'----------
   1',T46,'------',T54,'-----------------')
807   FORMAT(2X,A6,I8,3X,I8,6X,0PF8.2,5X,I4,7X,0PF8.4)
808   FORMAT(2X,A6,I8,3X,I8,6X,0PF8.2,5X,I4,7X,1PE8.2)
809  FORMAT(T54,'-----------------')
810  FORMAT(T33,'Total ',A7,' conc. =     ',0PF8.4)
811  FORMAT(T33,'Total annual conc.  =     ',0PF8.4)
812  FORMAT(T33,'Total ',A7,' conc. =     ',1PE8.2)
813  FORMAT(T33,'Total annual conc.  =     ',1PE8.2)
814  FORMAT(/,9X,'The total ',A7,' conc. is ',F8.4,' %',' of the PSD',
   < /,
   1 4X,'Class I ',A7,' increment for ',A4,'(',I5,' micrograms/m**3)')
815  FORMAT(/,9X,'The total ',A7,' conc. is ',1PE8.2,' %',' of the PSD
   <',/,
   1 4X,'Class I ',A7,' increment for ',A4,'(',I5,' micrograms/m**3)')
816  FORMAT(/,9X,'The total annual conc. is ',F8.4,' %',' of the PSD',
   < /,
   1 4X,'Class I annual increment for ',A4,'(',I5,' micrograms/m**3)')
817  FORMAT(/,9X,'The total annual conc. is ',1PE8.2,' %',' of the PSD
   <',/,
   1 4X,'Class I annual increment for ',A4,'(',I5,' micrograms/m**3)')
8001 FORMAT(A1,A70,' *********',/)
     CLOSE(UNIT=9)
```

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```
C    ******************  PRINT THE RESULT FILE ?  ******************
      IF(PRDEST.EQ.'P')THEN
       WRITE(*,'(//,'' Is the PRINTER (LPT1) ready: Y or N?  '')')
       READ(*,'(A1)')ANS
       IF(ANS.EQ.'Y'.OR.ANS.EQ.'y')THEN
        I=SYSTEM('PRINT MODEL.PRT'C)
       ELSE
        I=SYSTEM('CLS'C)
        WRITE(*,'(//,'' Result file MODEL.PRT cannot be printed by this
     1program'',/,14X,''until LPT1 is ready!  '')')
        WRITE(*,'('' Hit ENTER to continue.  '')')
        READ(*,'(A1)')ANS
       END IF
      END IF
C    ***********************************************************************
      RETURN
      END
      SUBROUTINE TABLEC(NUMT,NLTAB,NUMAC,NTP)
      DIMENSION NTP(5)
C     NTP(i) IS INDICATOR THAT TABLE i BEGINS AT THE TOP OF A NEW PAGE
      NLPAGE=60
      IT=0
      NLPB=0
    1 IT=IT+1
      IF(IT.GT.NUMT)GO TO 10
      NLP=NLTAB+NUMAC+(6-IT)/5+NLPB
      IF(NLP.LE.NLPAGE)THEN
       NLPB=NLP
       GO TO 1
      ELSE
       NTP(IT)=1
       NLPB=NLTAB+NUMAC
       GO TO 1
      END IF
   10 CONTINUE
      RETURN
      END
```

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