UCRL-MA-105607

USER'S MANUAL FOR SLAB: AN ATMOSPHERIC DISPERSION MODEL FOR DENSER-THAN-AIR RELEASES

Donald L. Ermak

June 1990

Lawrence Livermore National Laboratory

Work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

USER'S MANUAL FOR SLAB: AN ATMOSPHERIC DISPERSION MODEL FOR DENSER-THAN-AIR RELEASES

Donald L. Ermak

Physics Department, Atmospheric and Geophysical Sciences Division
University of California, Lawrence Livermore National Laboratory
Livermore, California 94550

June 1990

The SLAB program was produced under the sponsorship of the U.S. Department of Energy. The Government retains certain rights therein.

The user may copy and distribute the SLAB program or include the SLAB program, in whole or in part, in another computer program provided that the following conditions are met:

1. No fee may be charged for copying or distributing the SLAB program or any part thereof.

2. The SLAB program may not be distributed, in whole, or in part, as part of any commercial product.

An enhanced and user supported commercial version of SLAB is available from:

Bowman Environmental Engineering
P. O. Box 29072
Dallas, TX 75229
(214) BEE-LINE.

TABLE OF CONTENTS

ABSTRACT . . . 1
1. INTRODUCTION . . . 3
2. THEORETICAL DESCRIPTION . . . 7
2.1 Model Description of Dense Gas Dispersion . . . 7
2.2 Model Organization . . . 9
2.3 Governing Dispersion Equations . . . 11
2.3.1 Steady state plume mode . . . 11
2.3.2 Transient puff mode . . . 16
2.3.3 Transition from plume to puff mode . . . 18
2.3.4 Cloud length and time-dependence in the plume mode . . . 19
2.4 Solution of the Dispersion Equations . . . 20
2.5 Dispersion Submodels . . . 23
2.5.1 Ambient velocity profile . . . 23
2.5.2 Entrainment rates . . . 25
2.5.3 Heat and momentum flux terms . . . 27
2.5.4 Thermodynamics model . . . 28
2.5.5 Plume rise . . . 32
2.6 Time-averaged Concentration . . . 37
2.6.1 Ensemble, spatial, and time averages . . . 37
2.6.2 Cloud meander . . . 39
2.6.3 Time-averaged volume concentration . . . 41
3. USER'S GUIDE . . . 43
3.1 Input File . . . 43
3.1.1 Source type and numerical substep parameter . . . 45
3.1.2 Source properties . . . 46
3.1.3 Spill parameters . . . 49
3.1.4 Field parameters . . . 51
3.1.5 Meteorological parameters . . . 53
3.1.6 Input file closure . . . 55
3.2 Calculational Flow . . . 55
3.2.1 Initialization . . . 55
3.2.2 Dispersion calculation . . . 56
3.2.3 Time-averaged concentration calculation . . . 59
3.3 Output File . . . 60
3.3.1 Problem description . . . 61
3.3.2 Instantaneous spatially-averaged cloud properties . . . 61
3.3.3 Time-averaged volume fraction . . . 63
3.4 Concluding Remarks . . . 65
4. NUMERICAL EXAMPLES . . . 67
4.1 Multiple Run, Evaporating Pool Release . . . 67
4.2 Two-Phase, Horizontal Jet Release . . . 93
4.3 Instantaneous Release . . . 111
4.4 Vertical Jet Release . . . 127
5. REFERENCES . . . 143

USER'S MANUAL FOR SLAB: AN ATMOSPHERIC DISPERSION MODEL FOR DENSER-THAN-AIR RELEASES

ABSTRACT

SLAB is a computer model that simulates the atmospheric dispersion of denser-than-air releases. The types of releases treated by the model include a ground-level evaporating pool, an elevated horizontal jet, a stack or elevated vertical jet, and an instantaneous volume source. Except for the evaporating pool source which is assumed to be all vapor, all of the remaining sources may be either pure vapor or a mixture of vapor and liquid droplets.

Atmospheric dispersion of the release is calculated by solving the conservation equations of mass, momentum, energy, and species. The conservation equations are spatially averaged so as to treat the cloud as either a steady state plume, a transient puff, or a combination of the two depending upon the duration of the release. A continuous release (very long source duration) is treated as a steady state plume. In the case of a finite duration release, cloud dispersion is initially described using the steady state plume mode and remains in the plume mode as long as the source is active. Once the source is shut off, the cloud is treated as a puff and subsequent dispersion is calculated using the transient puff mode. For an instantaneous release, the transient puff dispersion mode is used for the entire calculation.

The mathematical description of the physics of heavy gas dispersion (gravity spread, reduced turbulent mixing, etc.), as well as the description of the normal atmospheric advection and turbulent diffusion processes, are inherently included in the conservation equations. The thermodynamics of liquid droplet formation and evaporation is treated by assuming local thermodynamic equilibrium. Transport of the vapor-droplet mixture is treated as a single fluid and neglects gravitational settling and ground deposition of the droplets. The thermodynamic effect of ground heating when the cloud is cooler than the ground surface is also included.

The time-averaged concentration predicted by SLAB depends on not only the various physical phenomena associated with the dispersion equations, but also on the specified concentration averaging time. This is due to cloud meander. As the concentration averaging time is increased, more cloud meander can occur resulting in an effectively wider cloud. In the limiting case of a trace gas release (where all dense-gas effects are negligible) over grassy terrain ($Z_0 = 0.02$ m) and a specified 15-minute concentration averaging time, SLAB yields a cloud concentration and width that corresponds to the values estimated by the standard Gaussian-plume dispersion curves for a rural environment.

Over the past six years, SLAB has been evaluated using a wide range of data obtained from both laboratory-scale and field-scale heavy-gas dispersion experiments. The code is written in standard Fortran 77 and is available on 5.25 inch, 360 kilo-byte floppy disk. Typical dispersion simulations require only a few minutes on an IBM-AT class personal computer. This report presents a theoretical description of the model, guidance for running the model and interpreting the results, and four example problems to illustrate the use of the model.

1. INTRODUCTION

SLAB is a computer model that simulates the atmospheric dispersion of denser-than-air releases. The model is based on concepts originally presented by Zeman (1982) for air entrainment into and gravity spread of a heavy gas cloud. The original version of SLAB (Morgan et al., 1983) dealt with evaporating pool releases and was a time-dependent version which gave solutions for the crosswind-averaged cloud properties as a function of time (t) and downwind distance (x). In order to significantly reduce the computer run time for typical simulations, a steady state version of SLAB (Ermak and Chan, 1985) was developed. This version calculated the crosswind-averaged properties as a function of only the downwind distance (x) and resulted in an improvement in the computer run time by a factor of 100 or more. All of the work on SLAB up until this point had been supported by the U.S. Department of Energy.

Further development of SLAB was supported jointly by the USAF Engineering and Services Center (starting in 1986) and the American Petroleum Institute (starting in 1987). The goal of this effort was to develop an improved version of SLAB that runs on IBM-compatible personal computers (PC) and is documented by a user's manual. As a result of this support, several major improvements and additional capabilities have been added to SLAB. These include: (a) the simulation of finite duration releases including an instantaneous release using transient puff dispersion calculations, (b) the simulation of elevated horizontal and vertical jet source releases, and (c) the thermodynamic treatment of liquid droplet formation and evaporation of both the ambient water vapor and the released emission.

The current version of SLAB can treat continuous, finite duration, and instantaneous releases from four types of sources: a ground level evaporating pool, an elevated horizontal jet, a stack or elevated vertical jet, and a ground-based instantaneous release. The evaporating pool source is assumed to be pure vapor in accordance with the evaporation process. All of the remaining sources may be either pure vapor or a mixture of vapor and liquid droplets. While the model is designed to treat denser-than-air releases, it will also simulate cloud dispersion of neutrally buoyant releases and includes lofting of the cloud if it becomes lighter-than-air.

Atmospheric dispersion of the release is calculated by solving the conservation equations of mass, momentum, energy, and species using the SLAB concept as illustrated in Fig. 1. To simplify the solution of the conservation equations, the equations are spatially averaged with the cloud modeled as either a steady state plume or a transient puff. A continuous release (very long source duration) is treated as a steady state plume. In the case of a finite duration release, cloud dispersion is initially described using the steady state plume mode and remains in the steady state plume mode as long as the source is active. Once the source is shut off, the cloud is treated as a transient puff and subsequent dispersion is calculated using the puff mode. For an instantaneous release, the transient puff dispersion mode is used for the entire calculation. Solution of the spatially-averaged conservation equations in either dispersion mode yields the spatially-averaged cloud properties.

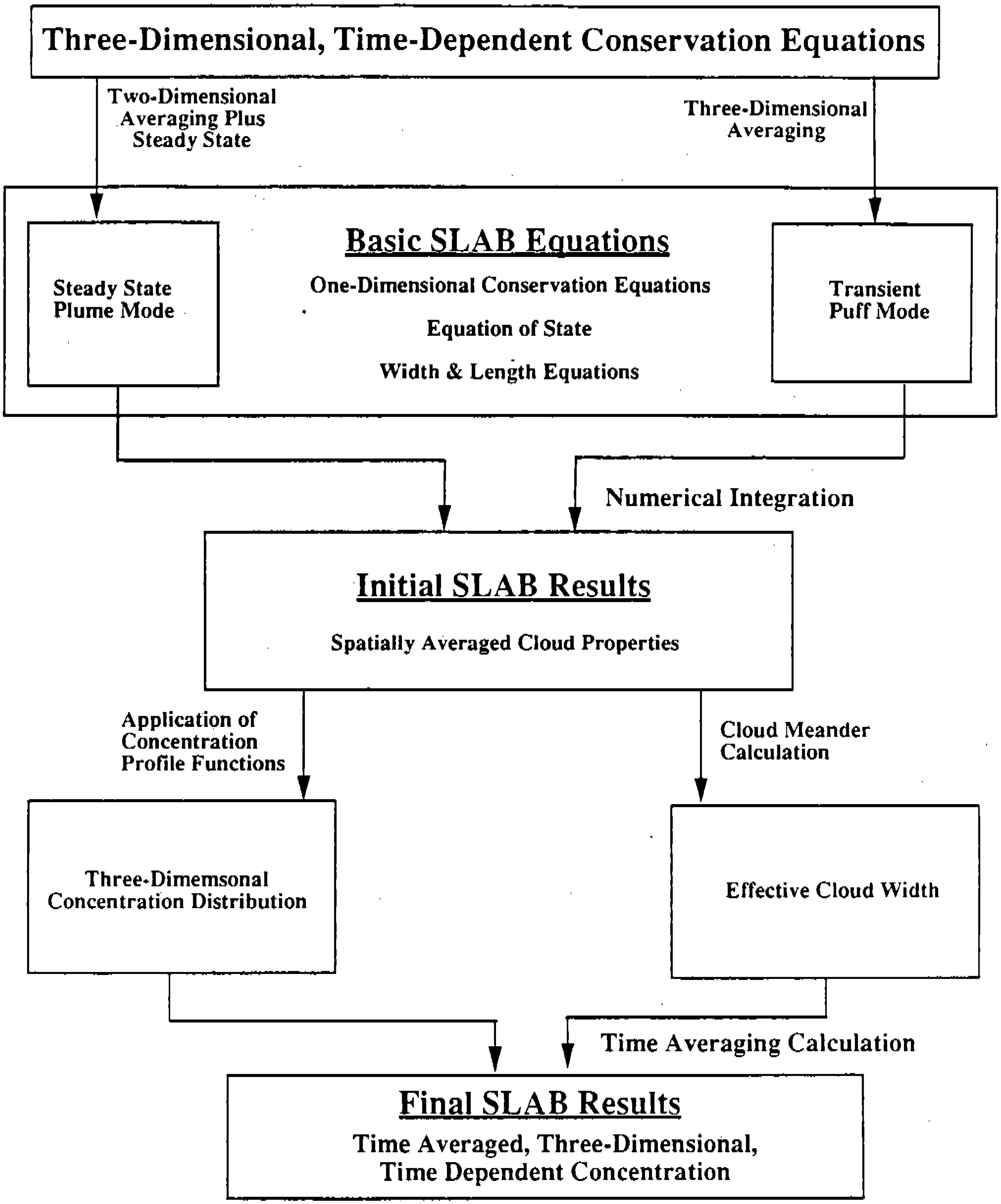

Figure 1. SLAB model concept.

To regain the three-dimensional variation of the concentration distribution, profile functions of an assumed form and dependence on the calculated cloud dimensions are applied. The time-averaged concentration is obtained in a two-step process. First, the effect of cloud meander on the effective width of the cloud is calculated, and then the concentration is averaged over time using the effective (meander included) width in the concentration profile function. This calculation yields the final result of the SLAB model, namely, the time-averaged concentration in time and space.

Over the past few years, SLAB predictions have been compared with a wide range of data obtained from both laboratory-scale and field-scale heavy gas dispersion experiments. These include comparisons with the LLNL Burro and Coyote series of liquefied natural gas (LNG) dispersion experiments (Ermak et al., 1982; Morgan et al., 1984) and the LLNL Eagle series of nitrogen tetroxide dispersion tests (Ermak and Chan, 1985). In these comparisons, SLAB performed quite well; for example, it predicted the lower flammability limit (LFL) distance in the LNG tests to within $\pm 15\%$. The submodel for the mixing of the atmosphere into the cloud was originally adapted from the results of wind tunnel experiments (Morgan et al., 1983) and, with some minor modifications, has been shown to compare well with other shear layer flows (Ermak and Chan, 1986). More recent comparisons with hydrogen fluoride releases from a horizontal jet have also been favorable (Blewitt et al., 1987a).

The purpose of this manual is to provide the users of SLAB with the information necessary to use the model effectively. A theoretical description of the model, including the governing equations and the method of solution, is presented in Section 2. Guidance in preparing the input file and in interpreting the code output is given in Section 3, along with a description of the calculational flow within the code. Finally, four example problems are included in Section 4 to illustrate the use of the model. The code is written in standard Fortran 77 and is available on 5.25 inch, 360 kilo-byte floppy disk. Typical dispersion simulations require only a few minutes on an IBM-AT class personal computer.

2. THEORETICAL DESCRIPTION

2.1 Model Description of Dense Gas Dispersion

The atmospheric dispersion of a large, denser-than-air release is affected by several physical phenomena that either do not occur or are unimportant in neutrally or positively buoyant, trace gas releases. These phenomena include: turbulence damping due to stable density stratification of the heavy gas cloud; alteration of the ambient velocity field due to gravity flow and the initial source momentum; and the thermodynamic effects on cloud temperature, buoyancy, and turbulence due to liquid droplet formation and evaporation, and to ground heating in the case of the release of a superheated or cryogenic liquid. Furthermore, the time scale of interest for a particular dense gas release may differ considerably from the long term dose concerns associated with typical atmospheric pollutants. For example, in combustible releases, one is concerned with the instantaneous concentration, while in a toxic gas release, one might be concerned about doses over minutes to hours, as well as the long term dose. In order to make meaningful predictions of the size and duration of the hazardous concentration region from a dense gas release, all of the significant physical phenomena need to be included and the appropriate concentration averaging time needs to be used.

To meet these requirements of the denser-than-air dispersion situation, the SLAB model is built upon a theoretical framework that starts with averaged forms of the conservation equations for mass, momentum, energy, and species (see Fig. 1). These equations are used to calculate the spatially-averaged properties of the dispersing cloud and are expressed in two forms representing two different dispersion modes: a steady state plume dispersion mode and a transient puff dispersion mode. The reason for these two dispersion modes is that the conservation equations have one form when the dispersing cloud is treated as a plume and another form when it is treated as a puff. The steady state plume form of the conservation equations is obtained by making the steady state assumption ($\partial/\partial t = 0$) and by averaging the equations over the crosswind directions (y and z). The transient puff form of the conservation equations is obtained by averaging the equations over all three spatial directions (x, y, and z). The theoretical framework of the SLAB model is completed by the inclusion of the equation of state (ideal gas law) and equations for the growth of the cloud dimensions (plume width in the steady state plume mode, and puff length and width in the transient puff mode).

In order to solve this basic set of equations, additional submodels and conditions are required. These submodels describe the dilution of the cloud due to turbulent mixing with the surrounding air, the formation and evaporation of liquid droplets within the cloud, and the heating of cold clouds at the ground surface. Turbulent mixing of the cloud with the ambient atmosphere is treated by using the entrainment concept which specifies the rate of air flow into the cloud. The thermodynamics of liquid droplet formation and evaporation is modeled by using the local thermodynamic equilibrium approximation. In this approximation, the ratio of liquid to vapor is determined by requiring the partial pressure of the vapor phase to be equal to the saturation pressure until all of the liquid is evaporated. The size of the liquid droplets is assumed to be sufficiently small so that the transport of the vapor-droplet mixture can be treated as a single fluid. Consequently, gravitational settling and ground deposition of the droplets are neglected. Finally, ground heating of the cloud when the cloud is cooler than the ground is treated by using the radiation boundary condition and a coefficient of surface heat transfer.

In the steady state plume mode, the conservation equations are averaged over the crosswind plane of the plume leaving downwind distance (x) as the single independent variable. In the transient puff mode, the conservation equations are averaged over all three dimensions of the cloud, leaving the downwind travel time (t) of the puff as the single independent variable. However, concentration can be expressed as both a function of downwind distance (x) and travel time (t) since these two parameters are related by the calculated downwind cloud velocity (U). The three-dimensional concentration distribution of the cloud is determined from the average concentration and by using similarity profiles that include the calculated cloud dimensions. Thus, the code is one-dimensional in both modes; however, since the cloud dimensions are also calculated and used to specify the spatial distribution of the cloud, the model is, in this sense, quasi-three-dimensional.

The basic conservation laws, along with the various submodels, form a set of coupled equations that mathematically describe the physics of heavy gas dispersion including: gravity spread which produces a wider and lower cloud, reduced turbulent mixing due to stable density stratification, the thermodynamic effects due to droplet formulation and evaporation and due to ground heating of the cloud, and the indirect effects of temperature change on density stratification and turbulent mixing with the ambient atmosphere. In addition, these equations also include the physical effects due to normal atmospheric advection and turbulent diffusion. The solution of this set of equations yields the instantaneous spatially-averaged concentration; density; temperature; downwind velocity; and cloud height, width, and length. (Here, the term "instantaneous" refers to the absence of cloud meander which tends to increase the effective width of the cloud.)

For most code users, the most important result is the time-averaged volume concentration as a function of travel time (t) from the source and as a function of the three spatial dimensions of downwind distance (x) from the source, crosswind distance (y) from the cloud centerline, and height (z) above ground level. In the SLAB model, the time-averaged concentration is calculated from the instantaneous (no meander) spatially-averaged concentration and from the assumed profile functions for the cloud distribution about the center-of-mass. These profile functions are based on the cloud height, width, and length, which are also calculated along with the solution to the conservation equations. The effects of plume meander are included by calculating the effective cloud width as a function of the concentration averaging time and the finite duration of the cloud. Thus, the predicted time-averaged volume concentration includes the effects of plume meander, the finite duration of the cloud, and the length of the averaging time.

2.2 Model Organization

The calculational flow within the SLAB code is shown in Fig. 2. There are three main stages to a typical simulation: source identification and initialization for dispersion, calculation of cloud dispersion, and calculation of the time-averaged concentration. As previously discussed, there are two atmospheric dispersion modes, the steady state plume mode and the transient puff mode. Access to these modes depends upon the type of source and the duration of the spill. After the instantaneous (no meander) spacially averaged cloud properties are determined by solving the conservation equations, the time-averaged volume concentration is calculated.

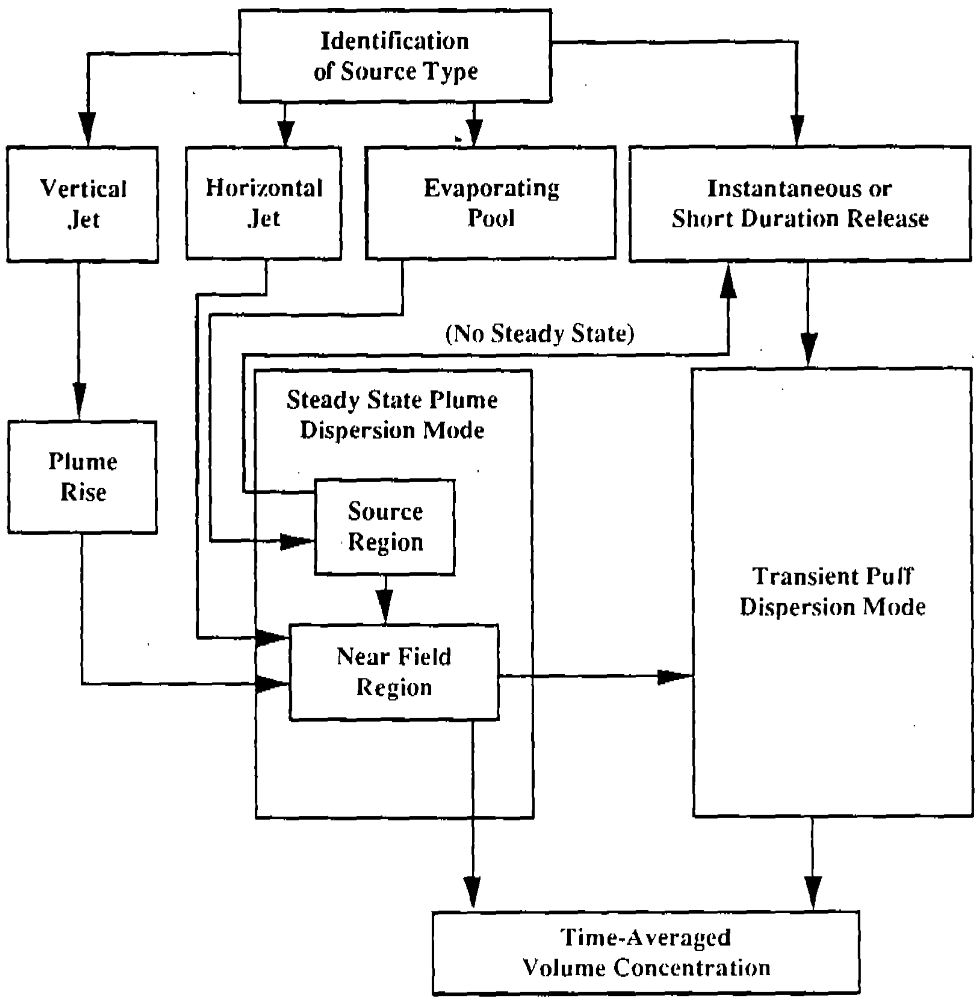

Figure 2. The calculational flow from source type to dispersion mode to time-averaged concentration.

Dispersion from an evaporating pool source and a horizontal jet source both begin in the steady state plume mode. This mode has two regions: a ***source region*** where source material is added to the dispersing cloud and a ***near field region*** where no additional source material is added to the cloud but it is still in steady state. The evaporating pool calculation begins in the source region and then proceeds to the near field region. The need to separate this calculation into two regions is a direct result of heavy gas phenomena and is explained in the following subsection. The horizontal jet source does not have a source region similar to the evaporating pool since it begins with a pure source emission vapor-droplet cloud traveling downwind at a speed equal to the jet exit velocity. Consequently, the dispersion calculation for the cloud produced from the horizontal jet source begins in the steady state near field region.

The situation for a vertical jet is similar to the horizontal jet in that neither has a source region where additional material is added to the dispersing cloud. In contrast to the horizontal jet, however, the vertical jet has a plume rise region where the cloud motion is mainly vertical. Consequently, the plume rise calculation is completed before entering the steady state near field plume dispersion calculation.

The dispersion calculation for a continuous, but limited release of duration t_{sd}, is initially conducted in the steady state plume mode. In this mode, downwind distance x is the single independent variable and time t is taken to be proportional to the amount of emitted mass within the plume. Calculation of the plume properties as a function of downwind distance x continues until the emitted mass within the plume, from the upwind edge of the cloud to the downwind distance x_t, is equal to one-half the released mass Q_s. At this downwind location, the dispersion calculation is switched from the plume mode to the puff mode. The puff center-of-mass is set equal to x_t so that the emitted mass within the puff is equal to the total mass released Q_s with half the mass upwind of x_t and half downwind. Time t is the single independent variable in the puff mode and the time of transition in the dispersion calculation from the plume to the puff mode is taken to occur at the end of the release when $t = t_{sd}$.

An exception to this procedure is taken when an evaporating pool release fails to reach steady state within the ***source region***. This condition is assumed to occur whenever the emitted mass within the ***source region*** of the steady state plume is greater than the total released mass Q_s. When this occurs, the steady state calculation is discarded and the entire calculation is restarted in the transient puff mode with the source taken to be a short duration evaporating pool release. In the case of an instantaneous source, there is also no steady state cloud. Consequently, the dispersion calculation for both an instantaneous source and a short duration evaporating pool release is conducted entirely in the transient puff dispersion mode.

Completion of the dispersion calculation in either mode yields the instantaneous (no meander) spatially-averaged cloud properties (mass and volume concentration, density, temperature, downwind velocity, cloud dimensions, etc.). As previously noted, the three-dimensional variation of the concentration distribution is regained by applying profile functions that are based on the calculated cloud dimensions. The calculation of the time-averaged concentration is conducted in two steps. First, the effective cloud width, which includes the increase due to cloud meander, is determined. (Recall, the "instantaneous" cloud width does *not* include the effect of cloud meander.) The amount of increase in width depends on the duration of the averaging time, the duration of the release, and the instantaneous cloud width. Secondly, the time-averaged concentration is calculated from the 'new' concentration distribution, which includes the effect of cloud meander in the effective cloud width.

2.3 Governing Dispersion Equations

2.3.1 Steady state plume mode

The steady state plume mode of SLAB is based on the steady-state crosswind-averaged conservation equations of mass, momentum, energy, and species and uses the air entrainment concept to account for turbulent mixing of the gas cloud with the surrounding atmosphere as shown in Fig. 3. The plume mode equations are:

Conservation Equations

Species

$$(\rho UBhm)' = \rho_s W_s B_s, \quad \text{where} \quad (\;)' = d(\;)/dx \quad , \tag{1}$$

Mass

$$(\rho UBh)' = \rho_a(V_e h + W_e B) + \rho_s W_s B_s \quad , \tag{2}$$

Energy

$$(\rho UBhC_p T)' = \rho_a(V_e h + W_e B)C_{pa}T_a + \rho_s W_s B_s C_{ps} T_s + f_{pc} + f_t \quad , \tag{3}$$

X-Momentum

$$(\rho UBhU)' = -0.5\alpha_g g\left[(\rho - \rho_a)\,Bh^2\right]' + \rho_a\,(V_e h + W_e B)\,U_a + f_u \quad , \tag{4}$$

Y-Momentum

$$(\rho UBhV_g)' = g(\rho - \rho_a)h^2 + f_{vg} \qquad \text{(Grounded Cloud)} \quad , \tag{5a}$$

$$\text{or} \qquad V_g = 0 \qquad \text{(Lofted Cloud)} \quad , \tag{5b}$$

Z-Momentum

$$(\rho UBhW_c)' = -g(\rho - \rho_a)Bh + f_w \qquad \text{(Lofted Cloud)} \quad , \tag{6a}$$

$$\text{or} \qquad W_c = -V_g \cdot Z_c/B \qquad \text{(Grounded Cloud)} \quad , \tag{6b}$$

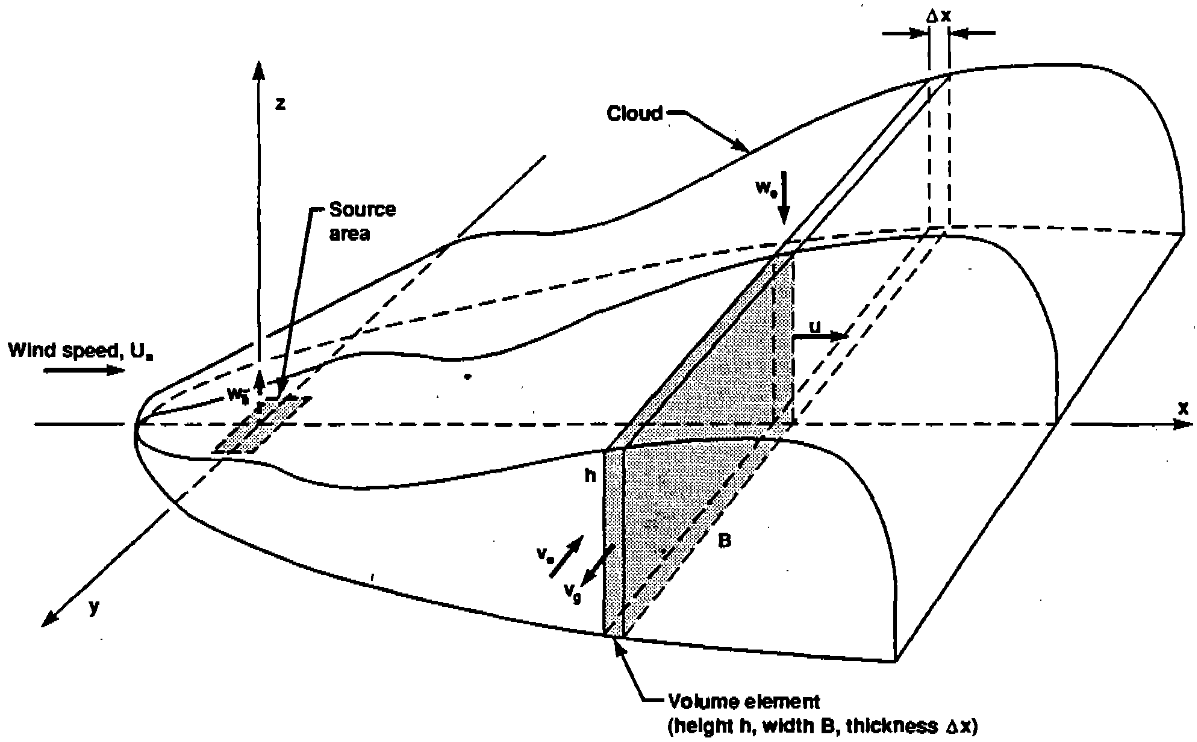

Figure 3. Dispersing heavy gas cloud, as depicted by SLAB in the plume dispersion mode.

Half-Width Equations

$$UB' = (\rho_a/\rho)V_e + V_g \quad , \tag{7}$$

$$Ub' = V_g \cdot b/B \quad , \tag{8}$$

Height Parameter Equation

$$UZ_c' = W_c \quad , \tag{9}$$

Equation of State

$$\rho = \rho_a \cdot T_a/[\alpha \cdot T + \gamma \cdot T_a] \quad , \tag{10}$$

where

$$\alpha = M_{ae}\left\{\frac{m_{da}}{M_a} + \frac{m_{wv}}{M_w} + \frac{m_{ev}}{M_s}\right\} \quad ,$$

$$\frac{1}{M_{ae}} = \left\{\frac{1-m_{wa}}{M_a} + \frac{m_{wa}}{M_w}\right\} \quad ,$$

$$\gamma = (\rho_a/\rho_{wl}) \cdot m_{wd} + (\rho_a/\rho_{sl}) \cdot m_{ed} \ ,$$

and

$$P_a = \rho_a \cdot R_c \cdot T_a / M_{ae} \ .$$

The first six equations are the conservation equations where x is downwind distance, ρ is density, U is velocity of the cloud in the wind direction, B and h are the cloud half-width and height (defined by Eq. (14) in the following paragraphs), m is mass concentration, C_p is specific heat, T is temperature, f_{pc} is the phase change energy, f_t is the ground heat flux, V_g is the horizontal crosswind gravity flow velocity, and f_u and f_{vg} are, respectively, the downwind and crosswind friction terms. The distinction between a grounded and lofted cloud is defined in Eq. (13) and is a function of the cloud height h and the height parameter Z_c. The subscript "a" refers to ambient air conditions and the subscript "s" refers to source properties. The horizontal and vertical entrainment rates are V_e and W_e, respectively, and the vertical source injection velocity is W_s. In an evaporating pool release the source flux $\rho_s W_s B_s$, is constant within the source region ($-B_s \leq x \leq B_s$) and zero outside.

In a horizontal jet release, $W_s = 0$ everywhere. The jet is treated as an elevated area-source pointing in the downwind direction with the jet center located at the downwind distance $x = 1$ m and height $z = h_s$. The source rate is $\rho_{sm} U_s A_s$ where U_s is the jet velocity, A_s is the plume area after the initial flash from pure liquid to a vapor-aerosol mixture, and ρ_{sm} is the density of the vapor-aerosol mixture. (When the release is pure vapor, A_s is the actual source area.) An additional equation is included to calculate the plume center height as the cloud travels downwind. Initially, the bottom of the jet may not be in contact with the ground; however, as the jet expands, it eventually makes contact with the ground.

In a vertical jet release, the source is treated as an elevated area-source pointing upward with the jet centered on the origin ($x = y = 0$) and having a height $z = h_s$. The source rate is $\rho_{sm} W_s A_s$ where W_s is the jet velocity, A_s is the source area after the initial flash from pure liquid to a vapor-aerosol mixture, and ρ_{sm} is the density of the vapor-aerosol mixture. As is the case with the horizontal jet, when the release is pure vapor, A_s is the actual source area. The plume rise portion of the cloud dispersion is calculated in a separate submodel, as described in Section 2.5.5. After the plume rise portion is completed, the dispersion calculation is continued in the near field steady state plume algorithm (see Fig. 2). In the steady state plume region, gravitational falling of the plume occurs if the cloud is denser-than-air and it is elevated above ground.

Use of the nearly uniform crosswind distribution assumption has been made in deriving the conservation equations. With this assumption, the average of the product is taken to be equal to the product of the averages, i.e., $\langle \rho U \rangle = \langle \rho \rangle \cdot \langle U \rangle$, where $\langle \ \rangle$ designates crosswind-averaged quantities. All of the cloud properties in Eqs. (1)–(6) are crosswind-averaged in the following manner

$$\rho = \rho(x) = \langle \rho(x,y,z) \rangle = \frac{1}{2Bh} \int_{-B}^{B} dy \int_{o}^{h} dz \cdot \rho(x,y,z) \quad , \tag{11}$$

and are functions of the downwind distance x only. Use of the average value notation $\langle\,\rangle$ is omitted since it always applies.

Equations (7)–(9) are cloud structure equations with B the cloud half-width, b a cloud half-width parameter, and Z_c a cloud height parameter. Both b and Z_c are not essential to the solution of the conservation equations. However, they are used to describe the shape of the three-dimensional volume concentration distribution and are described later in this section.

Equation (10) is the ideal gas law for a three-species system (dry air, water, and source emission) with the possibility of two of the species (water and source emission) existing as either vapor or liquid droplets. The parameters ρ_a, T_a, and P_a are the ambient air density, temperature, and pressure; m_{da}, m_{wv}, and m_{ev} are the average mass concentration of dry air, water vapor, and emission vapor; M_a, M_w, and M_s are the molecular weights of dry air, water, and the source emission; ρ_{wl} and ρ_{sl} are the liquid densities of water and source liquid; m_{wd} and m_{ed} are the mass concentrations of water and source emission in liquid droplet form; and R_c is the gas constant for an ideal gas. The relationship between the vapor and liquid fractions is described in the thermodynamics Subsection 2.5.4.

As previously noted, solution of the above equations is divided into two regions for the evaporating pool release. These regions are the source region where $W_s > 0$ and the near field steady state region beyond the source where $W_s = 0$. The reason for this separation is that gravity spread of the denser-than-air cloud manifests itself differently in these two regions. This can be seen in the actual dispersion of a denser-than-air cloud from an evaporating pool source. When the source rate and source density are sufficiently high and the ambient wind velocity is sufficiently low, the dispersing cloud in the source region will flow horizontally in all directions (gravity flow) including the upwind direction. This effectively increases the area of the source region until it is large enough to entrain sufficient air into the cloud to transport it downwind. Beyond the source region, gravity flow occurs only in the crosswind directions and there is no upwind flow.

The horizontal expansion of the cloud in all directions over the source region is manifest in SLAB in an analogous manner. Under the conditions cited above (namely, high source rate and density, and low ambient wind speed), there is no real solution to the conservation equations unless the source area is increased while keeping the source rate (kg/s) constant. In SLAB, the code searches for the minimum source area for which there is a real solution. The expansion of the source area in order to solve the conservation equations is a direct effect of the higher density of the source emission compared to that of air. If the source density is less than or equal to that of the ambient atmosphere, this expansion does not occur no matter how large the source rate or how small the ambient wind velocity. Beyond the source region, there is always a real solution to the conservation equations and gravity flow occurs only in the crosswind direction.

The solution of these equations yields the crosswind-averaged cloud properties (ρ, m, T, U, etc.) and the cloud size and shape parameters (B, b, h, and Z_c). One additional cloud property of interest is the crosswind-averaged volume concentration C, which is calculated from the mass concentration m as follows

$$C = \frac{M_a \cdot m}{M_s + (M_a - M_s) \cdot m} \quad . \tag{12}$$

Both the mass concentration m and the volume concentration C are expressed as fractions with values ranging from 0.0 to 1.0.

The three-dimensional volume concentration distribution $C(x, y, z)$ is obtained by assuming the following crosswind profile

$$C(x,y,z) = 2 \cdot B \cdot h \cdot C(x) \cdot C_1(y,b,\beta) \cdot C_2(z,Z_c,\sigma) \quad , \tag{13}$$

where

$$C_1(y,b,\beta) = \frac{1}{4b}\left[\mathrm{erf}\left(\frac{y+b}{\sqrt{2}\cdot\beta}\right) - \mathrm{erf}\left(\frac{y-b}{\sqrt{2}\cdot\beta}\right)\right] \quad ,$$

$$B^2 = b^2 + 3\beta^2 \quad ,$$

$$C_2(z,Z_c,\sigma) = \left(\frac{1}{2\pi}\right)^{1/2} \cdot \frac{1}{\sigma} \cdot \left[\exp\left(-\frac{(z-Z_c)^2}{2\cdot\sigma^2}\right) + \exp\left(-\frac{(z+Z_c)^2}{2\cdot\sigma^2}\right)\right] \quad ,$$

$$\sigma^2 = \begin{cases} h^2/12 \, , & Z_c > h/2 \text{ (lofted)} \\ (h - Z_c)^2/3 \, , & Z_c \le h/2 \text{ (grounded)} \end{cases} \quad ,$$

and erf is the error function, exp is the exponential function, and the average volume concentration $C(x)$ is defined in Eq. (12). The horizontal profile function $C_1(y, b, \beta)$ is uniform when $\beta = 0$ and approaches a Gaussian when $\beta \gg b$. The half-width parameters b and β are such that the ratio of b to β remains constant under the influence of the horizontal gravity flow velocity V_g. Thus, gravity spread stretches $C_1(y, b, \beta)$ but does not change its shape. Only horizontal entrainment (V_e) makes $C_1(y, b, \beta)$ approach a Gaussian shape. The vertical profile function allows for both grounded plumes ($Z_c \le h/2$) and elevated plumes ($Z_c > h/2$). Initially, the value of Z_c is zero for an evaporating pool source and is $Z_c = h_s$ for a horizontal or vertical jet source.

An undesirable result of using a Gaussian vertical profile is that the peak concentration at the cloud centerline can exceed 1.0 when the average concentration is greater than 0.72. At these high average concentration levels a profile approaching a square wave would be more appropriate. However, to overcome this difficulty at these very high concentration levels, a maximum value of 1.0 is permitted, rather than change the profile. This difficulty does not occur in the horizontal direction due to the use of the error function profile. The cloud half-width B and height h are related to the mean square width and height of the cloud by

$$B^2 = 3\sigma_y^2 = 3\int_{-\infty}^{\infty} dy \cdot y^2 \cdot C_1(y,b,\beta) \quad \text{and} \tag{14}$$

$$h^2 = 3\sigma_z^2 = 3\int_{o}^{\infty} dz \cdot z^2 \cdot C_2(z,b,\beta) \quad .$$

2.3.2 Transient puff mode

The transient puff mode of SLAB is based upon the volume-averaged conservation equations for mass, momentum, energy, and species and, as before, uses the air entrainment concept to account for turbulent mixing of the cloud with the surrounding atmosphere. In this form of the conservation equations, the cloud is treated as a puff (see Fig. 4) and the independent variable is the downwind travel time, t, of the puff center-of-mass. Also included are equations for the downwind location of the puff center-of-mass X_c, the puff length parameters B_x and b_x, and the puff width parameters B_y and b_y. These equations are:

Conservation Equations

Species

$$\left(\rho B_x \dot{B}_y hm\right) = \rho_s W_s B_s^2 \quad , \text{ where } \quad (\dot{\ }) = d(\ )/dt \quad , \tag{15}$$

Mass

$$\left(\rho B_x \dot{B}_y h\right) = \rho_a \left[\left(V_{ex} B_y + V_{ey} B_y\right) h + W_e B_x B_y\right] + \rho_s W_s B_s^2 \quad , \tag{16}$$

Energy

$$\left(\rho B_x \dot{B}_y h C_p T\right) = \rho_a \left[\left(V_{ex} B_y + V_{ey} B_x\right) h + W_e B_y\right] C_{pa} T_a + \rho_s W_S B_s^2 C_{ps} T_s \\ + B_x \left(f_{pc} + f_t\right) \quad , \tag{17}$$

X-Momentum (Translation)

$$\left(\rho B_x \dot{B}_y hU\right) = \rho_a \left[\left(V_{ex} B_y + V_{ey} B_x\right) h + W_e B_x B_y\right] U_a + B_x f_u \quad , \tag{18}$$

X-Momentum (Gravity Flow)

$$\left(\rho B_x \dot{B}_y h U_g\right) = g \left(\rho - \rho_a\right) h^2 B_x + B_x f_{vg} \qquad \text{(Grounded Cloud)} \quad , \tag{19a}$$

$$\text{or} \qquad U_g = 0 \qquad \text{(Lofted Cloud)} \quad , \tag{19b}$$

Y-Momentum

$$\left(\rho B_x \dot{B}_y h V_g\right) = g \left(\rho - \rho_a\right) h^2 B_y + B_x f_{vg} \qquad \text{(Grounded Cloud)} \quad , \tag{20a}$$

$$\text{or} \qquad V_g = 0 \qquad \text{(Lofted Cloud)} \quad , \tag{20b}$$

Z-Momentum

$$\left(\rho B_x \dot{B}_y h W_c\right) = -g \left(\rho - \rho_a\right) h B_x B_y + B_x f_w \qquad \text{(Lofted Cloud)} \quad , \tag{21a}$$

$$\text{or} \qquad W_c = -\left(V_g / B_y - U_g / B_x\right) Z_c \qquad \text{(Grounded Cloud)} \quad , \tag{21b}$$

Center-of-Mass

$$\dot{X}_c = U - \left(\rho_s W_s B_s^2 X_c / \rho B_x B_y h\right) \quad , \tag{22}$$

Half-width Equations

$$\dot{B}_y = \left(\rho_a / \rho\right) V_{ey} + V_g \quad , \tag{23}$$

$$\dot{b}_y = V_g \cdot b_y / B_y \quad , \tag{24}$$

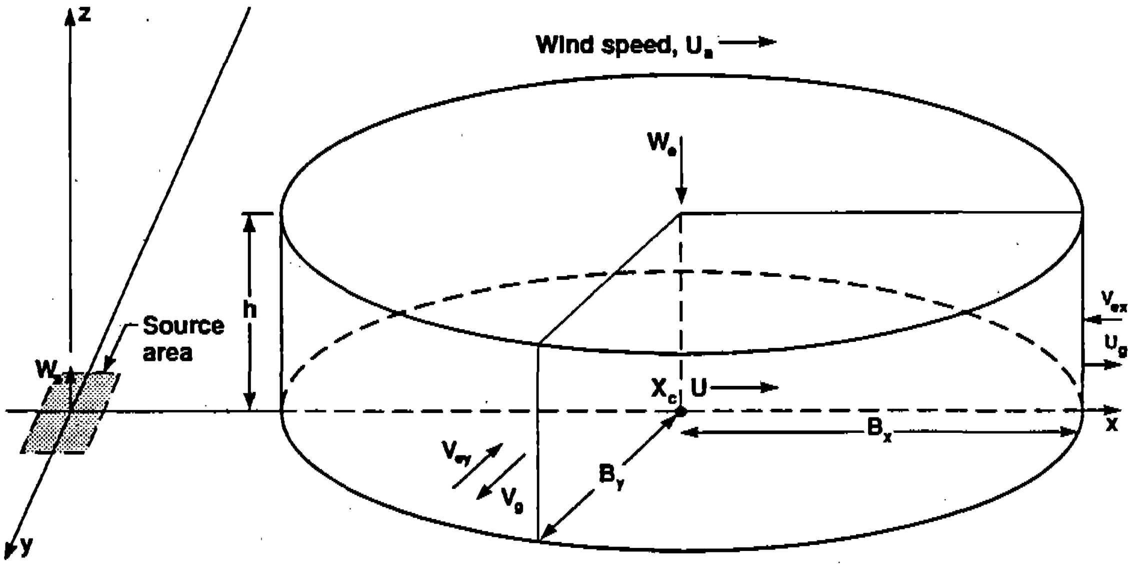

Figure 4. Dispersing heavy gas cloud as depicted by SLAB in the puff dispersion mode.

<u>Half-Length Equations</u>

$$\dot{B}_x = (\rho_a/\rho) V_{ex} + U_g \quad , \tag{25}$$

$$\dot{b}_x = U_g \cdot b_x/\beta_x \quad . \tag{26}$$

Here V_{ex} and V_{ey} are the horizontal downwind and crosswind entrainment rates, respectively. The remaining parameters are as defined in Eqs. (1)–(10). These equations are analogous to the plume equations and are solved in a similar manner along with the equation of state, Eq. (10). All of the cloud properties are averaged over the three dimensions of the cloud in the following manner

$$\rho = \rho(t) = \langle \rho(x,y,z,t) \rangle = \frac{1}{4B_x B_y h} \int_o^\infty dz \int_{-\infty}^\infty dy \int_\infty^\infty dx \rho(x,y,z,t) \quad . \tag{27}$$

As before, use of the average value notation $\langle\ \rangle$ is neglected since it applies to all the cloud properties defined above. The relationship between the three half-length parameters (B_x, b_x, and β_x) and the three half-width parameters (B_y, b_y, and β_y) is the same as the relationship between the three plume half-width parameters (B, b, and β), as given in Eq. (13). In addition, the cloud dimensions (B_x, B_y, h) are related to the mean square length, width, and height of the cloud in an analogous manner to Eq. (14).

The three-dimensional, time-dependent volume concentration $C(x,y,z,t)$ for the puff is given by

$$C(x,y,z,t) = 4 \cdot B_x \cdot B_y \cdot h \cdot C(t) \cdot C_1(x - X_c, b_x, \beta_x) \cdot C_1(y, b_y, \beta_y) \cdot C_2(z, Z_c, \sigma) \quad . \tag{28}$$

The average puff volume concentration $C(t)$ is obtained from the average puff mass concentration m using Eq. (12), where the independent variable is now downwind travel time t rather than downwind travel distance x. The crosswind $C_1(y, b_y, \beta_y)$ and vertical $C_2(z, Z_c, \sigma)$ profile functions are given by Eq. (13) where b_y, β_y, Z_c, and σ are now functions of t rather than x. The additional profile function $C_1(x - X_c, b_x, \beta_x)$ for the puff concentration distribution in the downwind direction has the same functional form as the crosswind profile function $C_1(y, b_y, \beta_y)$ where $x - X_c(t)$, $b_x(t)$, and $\beta_x(t)$ replace y, $b_y(t)$, and $\beta_y(t)$, respectively.

2.3.3 Transition from plume to puff mode

The puff dispersion mode can be entered at the beginning of a simulation by specifying an instantaneous or short duration evaporating pool source, or in the middle of a simulation after the release is completed and the steady state period is over. In the latter case, there is a transition in the calculation of the spatially-averaged cloud properties from the steady state plume equations to the transient puff equations. As described in the previous sections, both sets of equations are derived from the conservation equations; however, in the steady state plume mode they are spatially averaged over the crosswind plane of the cloud, while in the transient puff mode they are spatially averaged over the entire volume of the cloud. To begin the puff mode calculation, it is necessary to define the time of this transition, and the cloud length and center-of-mass at this time.

The time of the transition from steady state plume dynamics to transient puff dynamics is taken to occur at the end of the release, $t = t_{sd}$. The downwind location of the cloud center-of-mass $X_c(t_{sd})$ at this time is obtained by calculating the total mass of the released material within the cloud as a function of downwind distance. The cloud center-of-mass is taken to be the downwind location at which the mass of released material within the cloud from the upwind edge to the center-of-mass is equal to one-half the total amount of material released. Thus,

$$\frac{1}{2} \cdot Q_s \cdot t_{sd} = 2 \cdot \int_{X_s}^{X_c(t_{sd})} dx \cdot \rho \cdot B \cdot h \cdot m \quad , \tag{29a}$$

where Q_s is the release rate; t_{sd} is the duration of release; ρ, B, h, and m are the crosswind-averaged cloud density, half-width, height, and mass fraction, respectively; X_s is the farthest upwind extent of the cloud; and $X_c(t_{sd})$ is the cloud center-of-mass at the time of transition, $t = t_{sd}$.

The cloud half length B_x at the transition time is defined in a manner that requires the volume-averaged (puff) cloud properties to be equal to the crosswind-averaged (plume) cloud properties at the time and downwind location of the transition. When the release is terminated, the volume-averaged (puff) mass fraction is given by

$$m_v = (Q_s \cdot t_{sd})/(4 \cdot \rho_v \cdot B_x \cdot B \cdot h)$$

and the crosswind-averaged (plume) mass fraction is given by

$$m_c = Q_s/(2 \cdot \rho_c \cdot U_c \cdot B \cdot h) \quad .$$

By requiring m and ρ to be continuous at the transition, that is $m_v = m_c$ and $\rho_v = \rho_c$, the cloud half-length at the transition is defined to be

$$B_x(t_{sd}) = \frac{1}{2} \cdot U_c \cdot t_{sd} \quad , \tag{30}$$

where B_x and U_c are evaluated at $t = t_{sd}$ and $x = X_c(t_{sd})$.

In addition, all of the remaining crosswind-averaged cloud properties (U_c, T_c, V_{gc}, etc.) and the respective volume-averaged properties (U_v, T_v, V_{gv}, etc.) are required to be equal at the transition. Consequently, all of the spatially-averaged cloud properties are smooth and continuous as the code switches from the steady state plume mode to the transient puff mode.

2.3.4 Cloud length and time-dependence in the plume mode

The approach taken in the previous section for the calculation of the cloud center-of-mass and half-length at the transition from the plume mode to the puff mode can be extended to a calculation of the properties for any time t during the release, $0 < t < t_{sd}$. Starting with the cloud center-of-mass, it is defined to be the downwind distance at which the mass of released material within the cloud from the upwind edge to the center-of-mass is equal to one-half the material released during time t. Therefore,

$$t = (4/Q_s) \int_{X_s}^{X_c(t)} dx \cdot \rho \cdot B \cdot h \cdot m \quad . \tag{29b}$$

Equation (29b) gives the time t when the center-of-mass is located at the downwind distance $x = X_c(t)$. An approximation to the half-length can be obtained by linearly interpolating from the initial cloud half-length B_{xs} to the value at the end of the release $B_x(t_{sd})$ given by Eq. (30). Thus, during the time interval $(0, t_{sd})$, the cloud half-length is approximated by

$$B_x(t) = B_{xs} + [B_x(t_{sd}) - B_{xs}] \cdot [X_c(t) - X_o] \,/\, [X_c(t_{sd}) - X_o] \quad , \tag{31}$$

where $X_o = X_c(o)$ is the initial location of the center-of-mass.

The values of X_s, B_{xs}, and X_o used in Eqs. (29b) and (31) are determined by the source geometry. For the three types of continuous sources treated in SLAB, they are:

Evaporating Pool Source	Horizontal & Vertical Jet Source
$X_s = -B_s$	$X_s = 1.0$
$B_{xs} = B_s$	$B_{xs} = 0.0$
$X_o = 0.0$	$X_o = 1.0$

When an evaporating pool source is selected, the cloud center-of-mass $X_c(t)$ is defined to be zero for any time t less than t_s where

$$t_s = (4/Q_s) \int_{-B_s}^{o} dx \cdot \rho \cdot B \cdot h \cdot m \quad .$$

During the time, $0 < t < t_s$, the cloud is assumed to be approaching steady state within the source region of the evaporating pool. After steady state is reached in the source region, $-B_s < x < B_s$, the cloud center-of-mass begins to travel downwind in accordance with Eq. (29b).

With the cloud center-of-mass and half-length defined for the plume region, the three-dimensional volume concentration given by Eq. (13) can be generalized to the *time-dependent* form used in the puff region and given by Eq. (28). Thus, the three-dimensional, time-dependent volume concentration in the plume region is given by

$$C(x,y,z,t) = 4 \cdot B_x \cdot B \cdot h \cdot C(x) \cdot C_1(x - X_c, b_x, \beta_x) \cdot C_1(y, b, \beta) \cdot C_2(z, Z_c, \sigma) \quad , \tag{13b}$$

where the functions C_1 and C_2 are defined in Eq. (13); $C(x)$ is the average volume concentration defined in Eq. (12); B, h, b, β, Z_c, and σ are all functions of x and are as defined in Eq. (13); and X_c, B_x, b_x, and β_x are all functions of time with X_c given by Eq. (29b), B_x given by Eq. (31), and the remaining length parameters are specified to be

$$\begin{aligned} b_x &= B_x \quad \text{and} \\ \beta_x &= 0 \quad . \end{aligned} \tag{31b}$$

In practice, the value of β_x is set equal to a very small value to avoid attempting to divide by zero.

During the release, $0 < t < t_{sd}$, the downwind profile function $C_1(x - X_c, b_x, \beta_x)$ is essentially a square wave that grows in length with time and, thereby, simulates the increase in cloud length as the plume extends downwind. After the release is completed, the cloud begins to disperse as a puff with entrainment occurring at both the leading and trailing edges of the cloud. Consequently, the value of β_x begins to grow and the downwind profile function $C_1(x - X_c, b_x, \beta_x)$ begins to transform in shape from a square wave to a Gaussian profile.

2.4 Solution of the Dispersion Equations

The basic model equations can be solved by direct numerical integration of the equations as given in the previous subsection. However, analytic solutions to some of these equations or parts of an equation can be obtained by rearranging the equations and defining new variables. This approach is used in SLAB since it will presumably provide more accurate results with less numerical error. In addition, this approach when applied to the momentum equation in the source region, provides insight into the mechanism for the expanded source area due to gravity flow. The following subsection outlines the approach used to solve the basic model equations in the steady state plume mode. Solution of these equations in the transient puff mode is analogous.

In the steady state plume dispersion mode, the basic model equations are given by Eqs. (1)–(10). A variable that is common to the first six equations is $R(x) = \rho U B h$. The value of R can be calculated by integrating Eq. (2) written as

$$R' = \rho a \left(V_e h + W_e B \right) + \rho_s W_s B_s \quad , \tag{2a}$$

where $W_s = 0$ outside the source. Equation (2a) is integrated in SLAB by use of the Runge-Kutta method. This method is used for all the integrations of the basic conservation equations.

With $R(x)$ determined by integrating Eq. (2a) the species equation, Eq. (1), can be integrated analytically and yields the following expression for the average cloud mass concentration

$$m = \begin{cases} \rho_w W_s B_s (x + B_s)/R & ; -B_s \leq x \leq B_s \\ 2\rho_s W_s B_s^2/R & ; x > B_s \end{cases} . \tag{1a}$$

The temperature equation, Eq. (3), can be expressed in an analytic form by defining the net ground heat flux

$$F_t(x) = \int_{xo}^{x} f_t(x) dx \quad ; \quad x = x_o + \delta x \ , \tag{3a}$$

and the net phase change energy

$$F_{pc}(x) = \int_{xo}^{x} f_{pc}(x) \ dx \quad , \tag{3b}$$

where δx is the incremental increase in downwind location, $f_t(x)$ [defined by Eq. (37)] is the ground heat flux, f_{pc} (see Section 2.3.4) is the energy change due to droplet evaporation and formation. Substituting Eqs. (1), (2), (3a), and (3b) into Eq. (3) and integrating yields the following expression for the average cloud temperature in terms of the new variable E

$$T = (R_o \cdot C_{po} \cdot T_o + E - E_o + F_{pc} + F_t) / (R \cdot C_p) \quad , \tag{3c}$$

where

$$E = R \cdot (1 - m) \cdot C_{pa} \cdot T_a + R \cdot m \cdot C_{ps} \cdot T_s$$

and the sub "o" indicates that the variable is to be evaluated at the downwind location x_o. In the absence of liquid droplets in the cloud, Eq. (3c) can be solved directly and then the average density ρ can be calculated from the equation of state, Eq. (10). However, this is not the case when droplet evaporation and formation occur. The net phase change energy term F_{pc} is highly dependent on temperature and density. Consequently, the temperature, density, and vapor/droplet mass fraction equations are highly coupled and are solved iteratively using Newton's method. Additional details regarding the phase change calculation are given in Section 2.5.4 on the thermodynamics model.

The downwind velocity equation, Eq. (4), is complicated by the gravity flow pressure term, but it can also be expressed in an analytic form. We again start by expressing the net ground friction and drag at the top of the cloud as

$$F_u(x) = \int_{xo}^{x} f_u(x) \ dx \quad , \tag{4a}$$

where $f_u(x)$ is the ground friction and drag at the top of the cloud, and is defined by Eq. (38). Substituting Eqs. (1) and (2) into Eq. (4), expressing the cloud height as $h = R/\rho UB$, and then integrating Eq. (4) yields a cubic equation for the velocity,

$$U^3 - U_e \cdot U^2 + U_g^3 = 0 \quad , \tag{4b}$$

where

$$U_e = (1-m)U_a + (R_o/R)\cdot\left[U_o - (1-m_o)\cdot U_{ao} + U_{go}^3/U_o^2\right] + F_u/R \quad ,$$
$$U_g^3 = 0.5\cdot\alpha_g\cdot g\cdot(\rho-\rho_a)\cdot R/\left(B\cdot\rho^2\right) \quad ,$$

and the sub "o" designates evaluation at x_o. Up until this point, U_a has been assumed to be constant. At this point, we allow the ambient wind velocity to depend upon height, that is $U_a = U_a(z)$. Equation (4b) is then modified by replacing U_a with $\overline{U}_a$ where the average ambient wind velocity is defined as

$$\overline{U}_a = \frac{1}{h}\int_o^h U_a(z)\,dz \tag{4c}$$

and Eq. (4c) is integrated using Simpson's rule. Returning to Eq. (4b), a positive real solution to this equation exists only when

$$U_g^3 \le U_m^3 = \frac{4}{27}\cdot U_e^3 \quad . \tag{4d}$$

Consequently, if the source rate and density is sufficiently large, a positive real solution may *not* exist (i.e., $U_g^3 > U_m^3$) within the source region ($-B_s < X < B_s$). When this condition occurs, the source area is increased while keeping the total source rate (kg/s) constant until the minimum source area solution is found. Physically, the enlargement of the source area corresponds to upwind gravity flow in the source region. Beyond the effective source region (i.e., $x > B_{se}$, where B_{se} is the effective source half-width and half-length), a solution to Eq. (4b) always exists once the solution has been established in the source region ($-B_{se} < x < B_{se}$). When more than one real, positive solution to Eq. (4b) exists, the largest is taken to be the physically meaningful one as it approaches U_a as the cloud conditions approach ambient conditions. This solution is given by

$$U = \frac{1}{3}\cdot U_e\cdot[1 + 2\cdot\cos\ (\phi/3)] \quad , \tag{4e}$$

where

$$\phi = \cos^{-1}\left(1 - 2\cdot U_g^3/U_m^3\right) \quad .$$

The gravity flow velocity is determined from Eq. (5a) by first defining a gravity flow function G as follows

$$G = R\cdot V_g \quad , \tag{5aa}$$

so that

$$G' = g(\rho-\rho_a)h^2 + f_v \quad . \tag{5ab}$$

The gravity flow velocity is then given by

$$V_g = (G - G_o + V_{go}\cdot R_o)/R \quad , \tag{5ac}$$

where the sub "o" designates the value at the beginning of the step. The value of G is determined by numerical integration of Eq. (5ab) using the Runge-Kutta method. Of course, when the cloud is lofted, then Eq. (5b) rather than Eq. (5a) applies, and $V_g = 0$. The solution for the vertical velocity, Eq. (6a) and (6b), is similar to that for Eq. (5a) and (5b).

The three remaining equations to be solved are those for the half width B, Eq. (7), the half width parameter b, Eq. (8), and the height parameter Z_c, Eq. (9). These three equations are solved numerically using the Runge-Kutta method. With all of the basic conservation equations and the equation of state solved, two variables of interest remain to be determined. They are the cloud height, which is calculated using the definition of R

$$h = R/\rho UB \tag{2b}$$

and the volume concentration, which is calculated from the mass concentration and molecular weights as given by Eq. (12).

2.5 Dispersion Submodels

2.5.1 Ambient velocity profile

The ambient wind velocity profile is derived from the following assumed gradient

$$\frac{dU_a}{dz} = \frac{U_{a*}}{kz} \cdot \Phi_m(z/L) \cdot g(z/H) \quad , \tag{32}$$

where U_a is the ambient wind velocity, U_{a*} is the ambient friction velocity, $k = 0.41$ is Von Karman's constant, z is height, L is the Monin-Obukhov length, H is the height of the mixing layer, Φ_m is the momentum Monin-Obukhov function, and $g(z/H)$ is a mixing layer function. The function $g(z/H) = 1 - z/H$, where $H = H(s) = 130 \cdot [2^{(7-s)}]$ and $s = 1, 6$ corresponds to the atmospheric stability classes A-F, respectively. (The SLAB code will accept values of s ranging from 0.5 to 7.5 with the integer values 1–6 corresponding to the classes A-F.) The momentum Monin-Obukhov function Φ_m is adapted from Dyer (1974). For stable conditions ($s > 4$)

$$\Phi_m(z/L) = 1 + 5 \cdot L^{-1} \cdot z/(1 + z/z_L(s)) \ , \tag{33a}$$

so that

$$U_a(z) = \frac{U_{a*}}{k} \left\{ ln(z/z_o) - \frac{(z - z_o)}{H} + 5 \cdot L^{-1} \cdot z_L \cdot \left[\left(1 + \frac{z_L}{H}\right) \cdot ln\left(\frac{z + z_L}{z_o + z_L}\right) - \frac{(z - z_o)}{H} \right] \right\} \ , \tag{34a}$$

where z_o is the surface roughness length. The stability parameter $z_L(s) = 1 + 0.8 \cdot (s - 4)$ for $s \geq 4$ puts a limit on the growth of Φ_m at large heights and results in better agreement with observation for values of $\sigma_z(x)$ in the trace gas dispersion limit (see the following subsection).

For unstable conditions ($s < 4$)

$$\Phi_m(z/L) = \Phi_{m\infty} + (1 - \Phi_{m\infty})/(1 + \tau z)^{1/2} \quad , \tag{33b}$$

where

$$\Phi_{m\infty} = 1/\left(1 - 16 \cdot z_L \cdot L^{-1}\right)^{1/4} \quad ,$$
$$\tau = -8L^{-1}/(1 - \Phi_{m\infty}) \quad , \text{ and}$$
$$z_L(s) = \exp(3.2 - 0.8 \cdot s) \quad , \quad s < 4 \quad .$$

The resultant velocity profile is

$$U_a(z) = \frac{U_{a*}}{k}\left\{ln(z/z_o) - \Phi_{m\infty} \cdot (z - z_o)/H \right. \tag{34b}$$
$$\left. - 2 \cdot (1 - \Phi_{m\infty}) \cdot \left[ln\left(\frac{1+x}{1+x_o}\right) - \left(x^{1/2} - x_o^{1/2}\right)/(\tau \cdot H)\right]\right\} \quad ,$$

where

$$x = (1 + \tau \cdot z)^{1/2} \quad \text{and} \quad x_o = (1 + \tau \cdot z_o)^{1/2} \quad .$$

These velocity profiles are used in the calculation of the average ambient velocity $\overline{U}_a$ used in Eqs. (4) and (18) and defined in Eq. (4c).

These forms of the velocity profile, Eqs. (31a) and (31b), are not defined for small heights when $z < z_o$. To overcome this difficulty, $U_a(z)$ is redefined for values of $z < e \cdot z_o = 2.72 \cdot z_o$. In this region

$$U_a(z) = C_1 \cdot z + C_2 \cdot z^2, \qquad z < 2.72 \cdot z_o \quad , \tag{34c}$$

where C_1 and C_2 are such that $U_a(z_t)$ and $U_a'(z_t), z_t = 2.72 \cdot z_o$, are equal to the original formulas. Thus, $U_a(z)$ and its first derivative are continuous everywhere for z on the interval $[O, H]$. Under neutral conditions and assuming that $z_o \ll H$ so that $U_a(z) \sim (U_{a*}/k) \cdot ln(z/z_o)$ near the ground, then $C_1 = U_{a*}/k \cdot z_t$ and $C_2 = 0$.

2.5.2 Entrainment rates

The vertical entrainment rate includes the effects of surface friction, differential motion between the air and the cloud, thermal convection due to ground heating, and damping of air-cloud mixing due to stable density stratification within the cloud relative to the ambient atmosphere. The formula used in SLAB is based on experimental data from several sources (Clauser, 1954; Bakke, 1957; Ellison and Turner, 1959; Lilly, 1968; Deardorff and Willis, 1982) and has been shown (Ermak and Chan, 1968) to agree with the observed entrainment rate in a number of independent stably stratified, shear flow experiments (Lofquist, 1960; McQuaid, 1976; Kantha et al., 1977). This formula is also a good approximation to the ambient entrainment rate when cloud density and velocity approach the ambient atmospheric values.

The vertical entrainment rate is defined to be

$$W_e = \frac{\sqrt{3} \cdot a \cdot k \cdot U_{e*} \cdot g(h/H)}{\Phi_h(h/L)} \quad , \tag{35a}$$

where the constants $a = 1.5$ and $k = 0.41$. The effective friction velocity $U_{e*} = (U_r/U_a(h)) \cdot U_*$ is used rather than the actual friction velocity U_* so that in the trace gas limit the concentration predicted by SLAB approaches the Gaussian plume value $C = Q/(\pi \cdot U_r \cdot \sigma_y \cdot \sigma_z)$, where U_r is a reference velocity. In SLAB, U_r is calculated within the code and is specified to be the ambient wind velocity at 4 m height. The profile function $g(h/H)$ accounts for the height of the mixing layer H (see Section 2.5.1) and is defined to be

$$g(h/H) = 1 - h/H \quad , \tag{35b}$$

as discussed in the previous subsection. The Monin-Obukhov function Φ is defined to be

$$\Phi_h(h/L) = \begin{cases} 1 + 5 \cdot h/L & , L \geq 0 \text{ (stable)} \\ 1/[1 - 16 \cdot h/L]^{1/2} & , L < 0 \text{ (unstable)} \end{cases} \quad , \tag{35c}$$

where the Monin-Okukhov length is given by

$$L^{-1} = \left[L_a^{-1} \cdot U_{a*}^2 - C_r \cdot g \cdot (\rho - \rho_a)/\rho\right] \Big/ U_*^2 \quad , \tag{35d}$$

$$L_a^{-1} = L_{ao}^{-1}/(1 + h/z_L) \quad ,$$

and $C_r = 0.025$, the acceleration of gravity $g = 9.8$ m/s, the length parameter z_L is a function of the ambient stability class (see the previous subsection), and L_{ao} is the ambient Monin-Obukhov length at ground level.

The ambient friction velocity is U_{a*} and the in-cloud value of the friction velocity U_* is defined to be

$$U_*^2 = U_{mg*}^2 + U_{mh*}^2 + U_{t*}^2 \quad , \tag{35e}$$

where

$$\begin{aligned} U_{mg*}^2 &= C_f^2 \cdot \left(U^2 + 0.25 V_g^2\right) + U_{s*}^2 \quad , \\ U_{s*}^2 &= 0.5 \cdot W_s \cdot U_a \quad , \\ C_f &= U_{a*}/\overline{U}_a \quad , \\ U_{mh*}^2 &= C_g \cdot \left[\delta U^2 + 0.25\,(\rho_a/\rho)^2\, V_g^2\right] \quad , \quad C_g = 0.0195 \quad , \\ \delta U &= (\rho_a/\rho) \cdot (\overline{U}_a - U) \quad , \end{aligned}$$

and

$$\begin{aligned} U_{t*}^3 &= \frac{C_t \cdot g \cdot (T_g - T) \cdot V_H \cdot h}{\frac{1}{2}(T_g + T)} \quad , \quad T_g = T_a \quad , \quad C_t = 0.14 \quad , \quad \text{and} \\ V_H &= C_f \cdot U_{mg*} \quad . \end{aligned}$$

Within the source region for an evaporating pool release, the addition of the term U_{s*}^2 to U_{mg*}^2, where U_{s*}^2 corresponds to the shear between the source and ambient flows, was found to qualitatively improve agreement with the observed cloud height over the source.

The horizontal crosswind entrainment rate is given by

$$V_{ey} = \sqrt{3}\left(V_a^2 + V_j^2\right)^{1/2} \quad , \tag{36a}$$

where

$$V_a = a_1 \cdot U / \left[1 + a_2 \cdot B \Big/ \left(2\sqrt{3} \cdot a_1\right)\right] \quad ,$$

$$a_1 = 0.08 \cdot S(L_a) \cdot F_a(t) \quad ,$$

$$a_2 = 0.0004 \quad ,$$

$$S(L_a) = \begin{cases} 1 - (C_f/C_{fo})^{1/2} \cdot (L_y/L_a); & L_a < 0 \quad , \\ 1/[1 + (C_f/C_{fo})^{1/2} \cdot (L_y/L_a)]; & L_a \geq 0 \quad , \end{cases}$$

$$C_{fo} = 0.086 \quad , \quad L_y = 10 \quad ,$$

$$F_a(t) = \left[\left(t + \tau e^{-t/\tau}\right) / t_o\right]^p \quad ,$$

$$t = \text{averaging time} \ ,$$

$$\tau = 10 \text{ s}, \quad t_o = 900 \text{ s} \quad , \quad p = 0.2 \quad ,$$

$$V_j = a \cdot k \cdot C_g^{1/2} \cdot \delta u \quad ,$$

and a, k, C_g, and δU were defined above in the explanation of the vertical entrainment rate. The V_j term represents an increase in V_e over the ambient level and is due to shear between the plume and the ambient atmosphere. It results in approximately equal values for W_e and V_e in the high speed, lofted jet situation.

The horizontal crosswind entrainment rate also includes the factor F_a which accounts for plume meander (see discussion in Section 2.6.2). As the averaging time is increased, more plume meander can occur so the effective plume width becomes larger. In the calculation of the instantaneous spatially-averaged properties from the conservation equations, cloud meander is taken to be absent. Consequently, a value of $t = 0$ is used in F_a so that cloud meander is excluded. The normalization time t_o is such that $F_a(t_o) = 1$ and it is the averaging time that is assumed to apply to the standard dispersion curves for a trace gas plume [see for example Gifford (1976) or Pasquill and Smith (1983)].

The horizontal downwind entrainment rate is given by

$$V_{ex} = \sqrt{3}\left(V_a^2 + V_s^2\right)^{1/2}, \tag{36b}$$

where V_a is defined in Eq. (36a) and

$$V_s = 0.6 \cdot (U_{a*}/k) \cdot \Phi_m(Z_r/L_a) \cdot g(Z_r/H) \quad ,$$

with $Z_r = Z_c + 0.5 \cdot \sigma$, Z_c and σ as given in Eq. (13), and Φ_m, g, U_{a*}, k, L_a, and H as defined in Section 2.5.1. The V_s term is a shear term and is due to the vertical shear (increase in velocity with height) in the ambient downwind velocity $U_a(z)$. The form of the expresion for this shear term is taken from Wilson (1981) and Chatwin (1968).

In the limiting case of a trace gas release where all dense-gas effects are negligible, SLAB yields a cloud concentration, width, and height that corresponds to the values estimated by the standard dispersion curves when the concentration averaging time $t_{av} = t_o$. Figure 5 shows the SLAB values for σ_y and σ_z in the trace gas limit. The σ_y and σ_z dispersion parameters are plotted as a function of downwind distance x for a specific value of the surface roughness z_o, and a range in Monin-Obukhov length corresponding to the stability categories A-F. The relationship between stability class and Monin-Obukhov length is taken from Golder (1976) with stability class given as a function of the inverse Monin-Obukhov length L^{-1} and surface roughness length z_o.

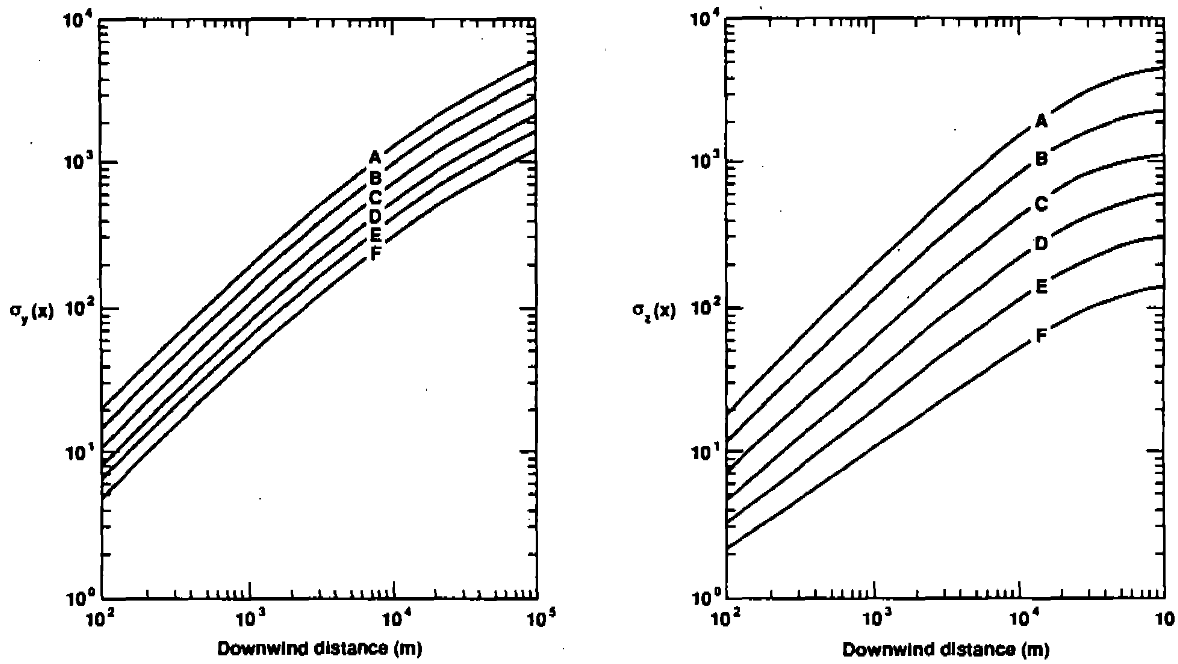

Figure 5. SLAB values of $\sigma_y(x)$ and $\sigma_z(x)$ in the trace gas limit where dense gas effects are absent. The σ_y and σ_z values are expressed as a function of downwind distance x and atmospheric stability class A-F. The surface roughness length is $z_o = 0.02$ m and the concentration averaging time is $t_{av} = 15$ min.

2.5.3 Heat and momentum flux terms

The flux terms are adapted from Zeman (1982). The thermal flux at the ground is given by

$$f_t = \rho \cdot B \cdot V_H \cdot C_p \cdot (T_g - T) \quad , \tag{37}$$

where V_H is given in Eq. (35e) and $T_g = T_a$.

The downwind velocity flux is due to the net ground friction and drag at the top of the cloud. It is defined to be

$$f_u = -\rho \cdot B \cdot \left\{ C_f^2 \cdot \left[(U - \delta U)^2 - \overline{U}_a^2 \right] + C_g \cdot \delta U^2 \right\} \quad , \tag{38}$$

where $\delta U = (\rho_a/\rho) \cdot (\overline{U}_a - U)$ as defined in Eq. (35e). The ambient friction velocity term is subtracted from the cloud friction velocity term so that f_u is equal to zero when the average cloud velocity equals the average ambient wind speed. The crosswind velocity flux is also composed of a ground friction term and a top of the cloud drag term, and is defined to be

$$f_v = -0.25\rho \cdot B\left[C_f^2 + C_g \cdot (\rho_a/\rho)^2\right] V_g^2 \quad . \tag{39}$$

2.5.4 Thermodynamics model

Liquid droplet formation and evaporation is governed by an equilibrium thermodynamics model within SLAB. Two species are allowed to form droplets: the ambient water vapor that enters the cloud and the released emission within the cloud. The governing equations are

1. the mass conservation equation for the released material, Eq. (1) or Eq. (15);
2. additional mass conservation equations for the dry air, total water, and the liquid/vapor fractions of water and emission;
3. the energy conservation (temperature) equation, Eq. (3) or Eq. (17);
4. the equation of state for a liquid droplet-vapor mixture, Eq. (10); and
5. the equilibrium condition that controls the liquid-vapor ratio for each species.

As discussed in the previous subsection, the mass concentration of released material m can be expressed in analytic form in terms of R where $R = \rho UBh$ in the plume mode and $R = \rho B_x B_y h$ in the puff mode. The result is given by Eq. (1a) for the plume mode and is repeated here along with the result for the puff mode.

Total Emission

Plume Mode:

$$m = \begin{cases} q_s \cdot (x + B_s)/(4 \cdot B_s \cdot R) & ; x \le B_s \\ q_s/(2 \cdot R) & ; x > B_s \end{cases} \tag{1a}$$

Puff Mode:

$$m = \begin{cases} (Q_{si} + q_{sc} \cdot t)/(4 \cdot R) & ; t \le t_{sd} \\ (Q_{si} + q_{sc} \cdot t_{sd})/(4 \cdot R) & ; t > t_{sd} \end{cases} \quad , \tag{15a}$$

where q_s is the source rate (kg/s) from either an evaporating pool or jet source in the steady state plume mode, Q_{si} is the instantaneously released mass (kg), and q_{sc} is the source rate (kg/s) from an evaporating pool source in the transient puff mode.

Similar equations can be obtained for each of the species of interest by integrating the appropriate species conservation equation. The results are:

Total Water

$$m_w = (1 - m) \cdot m_{wa} \tag{40a}$$

Dry Air

$$m_{da} = (1 - m) \cdot (1 - m_{wa}) \tag{40b}$$

Water Vapor

$$m_{wv} = m_w + (R_o/R) \cdot (m_{wvo} - m_{wo}) + \delta m_{wpc} \tag{40c}$$

Emission Vapor

$$m_{ev} = m + (R_o/R) \cdot (m_{evo} - m_o) + \delta m_{epc} \tag{40d}$$

Water Droplets

$$m_{wd} = m_w - m_{wv} \tag{40e}$$

Emission Droplets

$$m_{ed} = m - m_{ev} \quad . \tag{40f}$$

In the above, m_{wa} is the ambient value of the mass concentration of water vapor, sub "o" designates the variable value at the beginning of the integration step, and δm_{wpc} and δm_{epc} are the increases in the water and emission vapor mass concentrations due to phase change during the spatial (plume mode) or temporal (puff mode) step.

The temperature equation can also be expressed in analytic form using R, the net ground heat flux F_t [see Eq. (3a)], and the phase change energy $E_{pc} = F_{pc}/R$ [see Eq. (3b)]. In this form, the temperature is given by

$$\begin{aligned} T = &[(1 - m) \cdot C_{paa} \cdot T_a + m \cdot C_{ps} \cdot T_s + (R_o/R) \\ &\cdot (C_{po} \cdot T_o - (1 - m_o) \cdot C_{paa} \cdot T_a - m_o C_{ps} \cdot T_s) + F_t/R + E_{pc}] / C_p \quad , \end{aligned} \tag{41}$$

where

$$\begin{aligned} C_{paa} &= (1 - m_{wa}) \cdot C_{ps} + m_{wa} \cdot C_{pwv} \quad , \\ C_p &= m_{da} \cdot C_{pa} + m_{wv} \cdot C_{pwv} + m_{wd} \cdot C_{pwl} + m_{ev} \cdot C_{ps} + m_{ed} \cdot C_{psl} \quad , \\ E_{pc} &= -\delta M_{wpc} \cdot \Delta H_w - \delta m_{epc} \cdot \Delta H_e \quad , \end{aligned}$$

and C_p is the specific heat of the in-cloud mixture with the following subscripts "a", "wv", "wl", "s", and "sl" indicating dry air, water vapor, water liquid, emission vapor, and emission liquid, respectively. The heat of vaporization is specified as ΔH with the subscripts "w" and "e" corresponding to water and emission.

The equation of state is given by Eq. (10) and is repeated here

$$\rho = \rho_a \cdot T_a/(\alpha \cdot T + \gamma \cdot T_a) \quad , \tag{10}$$

where

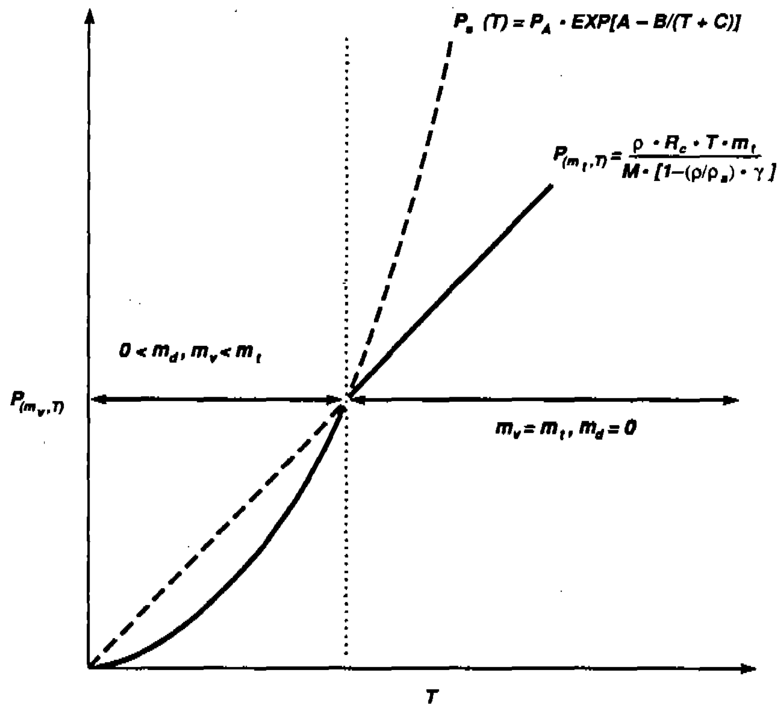

Figure 6. Partial pressure as a function of temperature T and vapor mass concentration m_v according to the local equilibrium thermodynamics model. Total mass concentration for this species is the sum of the vapor and droplet components, $m_t = m_v + m_d$.

$$a = M_{ae}\left\{\frac{m_{da}}{M_a} + \frac{m_{wv}}{M_w} + \frac{m_{ev}}{M_s}\right\} \quad ,$$

$$\frac{1}{M_{ae}} = \left\{\frac{1 - m_{wa}}{M_a} + \frac{m_{wa}}{M_w}\right\} \quad ,$$

$$\gamma = (\rho_a/\rho_{wl}) \cdot m_{wd} + (\rho_a/\rho_{sl}) \cdot m_{ed} \quad ,$$

$$P_a = \rho_a \cdot R_c \cdot T_a/M_{ae} \quad ,$$

and where R_c is the gas constant.

The remaining equations specify the vapor concentration using the local equilibrium condition which requires the partial pressure of the vapor phase for each species to be the lesser of (1) the partial pressure with the total mass fraction in the vapor phase and (2) the saturation pressure. This is shown graphically in Fig. 6 and can be expressed mathematically as follows. Considering one species where the total mass concentration is related to the vapor and droplet concentrations by $m_t = m_v + m_d$, the partial pressure with $m_v = m_t$ is

$$P(m_t, T) = \frac{\rho \cdot R_c \cdot T \cdot m_t}{M \cdot [1 - (\rho/\rho_a)\gamma]} \quad . \tag{42}$$

The saturation pressure can be expressed in the form

$$P_s(T) = P_a \cdot exp[A - B/(T + C)] \quad , \tag{43a}$$

where A, B, and C are saturation pressure constants. The local equilibrium condition can be expressed as follows

(1) if $P(m_t, T) < P_s(T)$, then

$$m_v = m_t \quad , \quad \text{but} \tag{44a}$$

(2) if $P(m_t, T) > P_s(T)$, then

$$m_v = \frac{P_s(T) \cdot m_t}{P(m_t, T)} \quad . \tag{44b}$$

Equations (42)–(44) apply to both water and the emission separately using the appropriate saturation pressure constants, molecular weight, and mass concentration. They specify the mass concentration of the vapor fraction as a function of temperature and the total mass fraction of the species present in the cloud.

The saturation pressure constants A, B, and C used in Eq. (43) are basic properties of the released material. The constants B and C are required input parameters; however, a default option (see Section 3.1.2) exists in which the Clapeyron equation is used to specify B, and C is assumed to be zero. When the default option is chosen, B is given by

$$B = \Delta H_e \cdot M_s / T_{bp} \quad , \tag{43b}$$

where ΔH_e is the heat of vaporization, M_s is the molecular weight, and T_{bp} is the boiling point temperature. The pressure is assumed to always be equal to 1 atm in SLAB. Consequently, the constant A is defined to be

$$A = B/(T_{bp} + C) \tag{43c}$$

and is not included in the input. The corresponding values of A, B, and C for water (due to the ambient humidity) are specified in the code and, therefore, none of these are included in the input.

The equations presented in this subsection form a set of dispersion and thermodynamics equations that are highly coupled in temperature and density. They are solved iteratively using Newton's method for each step of the integration in space (plume mode) or time (puff mode).

2.5.5 Plume rise

The plume from a vertical jet or stack release initially rises until a maximum plume height is attained. In SLAB, the plume rise region is described using empirical equations obtained from the results of wind tunnel and field experiments. Three types of jets are considered: denser-than-air jets ($\rho_s > \rho_a$), momentum jets ($\rho_s = \rho_a$), and buoyant jets ($\rho_s < \rho_a$). Subsequent dispersion of the plume beyond the plume rise region is calculated in SLAB by solving the conservation equations as described in Section 2.3.

2.5.5.1 Denser-than-air jet

The denser-than-air plume rise equations are taken from wind tunnel results obtain by Hoot, Meroney, and Peterka (1973). They present the following equations for the maximum plume rise h_{pr}, the downwind location at maximum plume rise X_{pr}, and the peak volume concentration at maximum plume rise C_{pk}

$$h_{pr} = 1.32 \cdot \left(R_v \cdot S_g \cdot F_r^2\right)^{1/3} \cdot D_s \quad , \tag{45a}$$

$$X_{pr} = \left(F_r^2/R_v\right) \cdot D_s = .435 \cdot h_{pr}^3 / \left(R_v^2 \cdot S_g \cdot D_s^2\right) \quad , \tag{45b}$$

$$C_{pk} = 1.69 \cdot R_v \cdot (D_s/h_{pr})^{1.85} \quad , \tag{45c}$$

where

$$D_s = \left(4/\pi^{1/2}\right) \cdot B_s = \text{ stack diameter} \quad ,$$

$$R_v = W_s/U_a \quad ,$$

$$S_g = \rho_s/\rho_a \quad ,$$

$$F_r = W_s / \left[g \cdot D_s \cdot (\rho_s - \rho_a)/\rho_a\right]^{1/2} \quad ,$$

and where B_s is the half-width of the source, W_s is the source velocity, U_a is the ambient wind speed at the height of the stack, ρ_s is the source density, ρ_a is the ambient air density, and g is the acceleration of gravity.

In SLAB, the conservation equations in the plume mode are expressed in terms of the crosswind-averaged cloud properties (C, m, ρ, T, etc.) rather than the peak values. Consequently, C_{pk} given by Eq. (45c) must be converted to a crosswind average C, and then the crosswind-averaged *mass* concentration m can be obtained using Eq. (12). Although the HMP experiments did not include releases at cryogenic temperatures or releases of aerosol-vapor mixtures, the above equations are assumed to be applicable for these situations. The remaining thermodynamic quantities (ρ, T, m_{ev}, m_w, etc.) are determined from the thermodynamics model described in the previous section.

At the point of maximum plume rise, the velocity of the plume is assumed to be totally in the downwind direction. Consequently, the vertical velocity of the cloud at maximum plume rise is taken to be zero. In HMP, the horizontal cloud velocity at maximum plume rise is taken to be equal to the ambient wind speed; however, the downwind cloud velocity can be considerably smaller if the density is sufficiently high. In this case, the plume will initially rise and then descend to the ground with little downwind motion. To include the possibility of this situation in SLAB, the downwind velocity is derived from the plume momentum equation [Eq. (4)] yielding

$$\rho B h U_{pr}^2 = (1-m)\rho B h U_{pr} U_a + \int_{-B_s}^{X_{pr}} dx \; \rho(2B+h) C_g (U_a - U_{pr})^2 \quad .$$

Approximating the frictional stress integral as the product of a coefficient times the velocity difference squared, the downwind velocity at maximum plume rise can be expresed in the form of a quadratic equation as follows

$$U_{pr}^2 = (1 - m) \cdot U_a \cdot U_{pr} + C_{gr} \cdot (U_a - U_{pr})^2 \quad ,$$

where

$$C_{gr} = 3 \cdot (2 + X_{pr}/B_s) \cdot C_g \quad .$$

Solving the above equation,

$$U_{pr} = \frac{U_a}{2 \cdot (1 - C_{gr})} \cdot \left\{ 1 - m - 2 \cdot C_{gr} + \left[(1 - m)^2 + 4 \cdot m \cdot C_{gr} \right]^{1/2} \right\} \quad . \tag{45d}$$

In the limit as $m \to 0$, $U_{pr} \to (1 - m) \cdot U_a \to U_a$ as assumed by HMP; and when $m \to 1$ and $X_{pr} \to 0$, U_{pr} approaches a minimum value. In SLAB, $C_g = 0.02$, so the minimum value is about $0.25\ U_a$.

To complete the description of the plume at the point of maximum plume rise, the plume half-width B, height h, and center height Z_c need to be determined. Conservation of mass requires the plume crosswind area to be

$$A_{pr} = 2 \cdot B_{pr} \cdot h_{pr} = Q_s / (\rho_{pr} \cdot U_{pr} \cdot m_{pr}) \quad .$$

Assuming that the plume height is 60% of the plume width (this is approximately the ratio of σ_z to σ_y in SLAB under ambient conditions for all stability classes) and that the minimum width is the stack diameter, then the plume dimensions at maximum plume rise are

$$B_{pr} = \max \left[(A_{pr}/2.4)^{1/2} \quad , \quad B_s \right] \tag{45e}$$

$$h_{pr} = 0.5 \cdot A_{pr} / B_{pr} \quad . \tag{45f}$$

The plume center height is

$$Z_{cpr} = h_s + h_{pr} \quad , \tag{45g}$$

where h_s is the stack height and h_{pr} is the plume rise calculated in Eq. (45a).

The above equations define the state of the plume at the maximum plume rise point. The plume is assumed to follow an elliptical path within the $x - z$ plane from the stack center (x_s, h_s) to the point of maximum plume rise $(x_s + X_{pr}, h_s + h_{pr})$ with the plume center (x, Z_c) given by

$$\frac{(x - x_s - X_{pr})^2}{X_{pr}^2} + \frac{(Z_c - h_s)^2}{h_{pr}^2} = 1 \quad . \tag{45h}$$

Some of the plume properties (principally B, h, Z_c, m, and C) are calculated in the plume rise region by interpolating between the two known values at the source and the maximum plume rise point. Beyond the plume rise region, all of the plume properties are calculated by solving the conservation equations with the values at the maximum plume rise point providing the initial conditions.

2.5.5.2 *Momentum and buoyant jets*

When the density of the released material is less than or equal to the ambient air density ($\rho_s \leq \rho_a$), plume rise is simulated in a somewhat more simplistic manner than when it is greater than that of air. In this case ($\rho_s \leq \rho_a$), the vertical jet source is replaced by an effective horizontal jet source located directly above the original vertical jet at a height h_{se} equal to the sum of the stack height h_s and the plume rise h_{pr}. Thus,

$$h_{se} = h_s + h_{pr} \quad . \tag{46a}$$

The calculation of plume rise h_{pr} is taken from the work of Briggs (1984). In the case of a momentum jet ($\rho_s = \rho_a$) the Briggs plume rise formula is

$$h_{pr} = 0.93 \cdot \left(\frac{W_s \cdot F_m}{\beta^2 \cdot U_a \cdot U_{a*}} \right)^{3/7} \cdot (h_s + h_{pr})^{1/7} \quad , \tag{46b}$$

where

$$F_m = \frac{4}{\pi} \cdot W_s \cdot B_s^2 \quad \text{and}$$
$$\beta = 0.4 + 1.2 \cdot U_a / W_s \quad .$$

In the case of a buoyant jet ($\rho_s < \rho_a$) the Briggs plume rise formula is

$$h_{pr} = 1.2 \cdot \left(\frac{F_b}{U_a \cdot U_{a*}^2} \right)^{3/5} \cdot (h_s + h_{pr})^{2/5} \quad , \tag{46c}$$

where

$$F_b = \frac{\frac{4}{\pi} \cdot g \cdot (\rho_a - \rho_s) \cdot W_s \cdot B_s^2}{\rho_a} \quad .$$

In both of these equations for h_{pr}, W_s is the source velocity, U_a is the ambient wind speed at the stack height h_s, U_{a*} is the ambient friction velocity, ρ_s is the source density, ρ_a is the ambient air density, g is the acceleration of gravity, and B_s is the half-width of the source.

The effective source is asumed to be unmixed with the surrounding air, so the effective mass fraction is $m_e = 1.0$, just as it is at the real source. The plume rise formulas given by Eqs. (46b) and (46c) are intended to account for all the vertical motion of the cloud; thus, subsequent dispersion is assumed to occur as if the cloud were neutrally buoyant. There are several ways in which the properties of the released material can be modified to insure that the cloud is neutrally buoyant. In SLAB, the effective source temperature and the specific heat of the released material are modified as follows

$$\begin{aligned} T_{se} &= (M_s/M_a) \cdot T_a \quad , \\ C_{ps} &= (M_a/M_s) \cdot C_{pa} \quad , \end{aligned} \tag{46d}$$

and ground heating of the cloud is turned off. In this way, the density at release and as the cloud disperses downwind remains equal to the ambient value, $\rho = \rho_a$. The molecular weight of the released material is not modified to preserve the relationship between volume and mass fraction [see Eq. (12)].

The effective source velocity is taken to be horizontal and equal to the ambient wind speed, $U_{se} = U_a$. In order to preserve the specified mass source rate Q_s, the effective area of the source must be

$$A_e = 2 \cdot B_e \cdot h_e = Q_s/(\rho_a \cdot U_a) \quad . \tag{46e}$$

As was the case with the dense-gas plume rise model, the cloud height after plume rise is assumed to be 60% of the cloud width [see Eqs. (45e) and (45f)].

The above equations define the effective source for the momentum ($\rho_s = \rho_a$) and buoyant ($\rho_a < \rho_a$) jet releases. This procedure changes the source from a vertical release at the height of the stack to a horizontal release at a height equal to the sum of the stack height and plume rise. Consequently, the release can now be treated as a neutrally buoyant, horizontal jet source with an effective source height given by Eq. (46a), an effective source velocity equal to the ambient wind speed, and an effective source area that is consistent with the specified mass source rate.

2.5.5.3 Limits to plume rise

There are three constraints that need to be placed on the calculated value of plume rise in order to be consistent with the rest of the SLAB model. The first constraint applies to all three types of vertical jets. The second and third apply specifically to the dense-gas jet and the buoyant jet, respectively.

The first constraint is the maximum allowable plume rise for any type of vertical release. In SLAB, the height of the mixing layer acts as an impenetrable boundary which keeps the cloud below this level. Consequently, the top of the cloud is never higher than the mixing layer height. When the calculated plume rise is such that the top of the cloud is above the mixing layer height, plume rise is reduced until the top of the cloud is at the mixing layer height.

The second and third constraints deal with plume rise in the limit as the source density ρ_s approaches the ambient air density ρ_a. This limit ($\rho_s = \rho_a$) is the momentum jet and, to be consistent, both the dense-gas and buoyant jet plume rise values need to approach the momentum jet plume rise value as ρ_s approaches ρ_a. Furthermore, since the force of gravity tends to pull a denser-than-air cloud down and push a buoyant cloud up, plume rise from a dense-gas ($\rho_s > \rho_a$) jet will always be less than the plume rise from an equivalent momentum ($\rho_s = \rho_a$) jet and plume rise from a buoyant ($\rho_s < \rho_a$) jet will always be greater than the plume rise from an equivalent

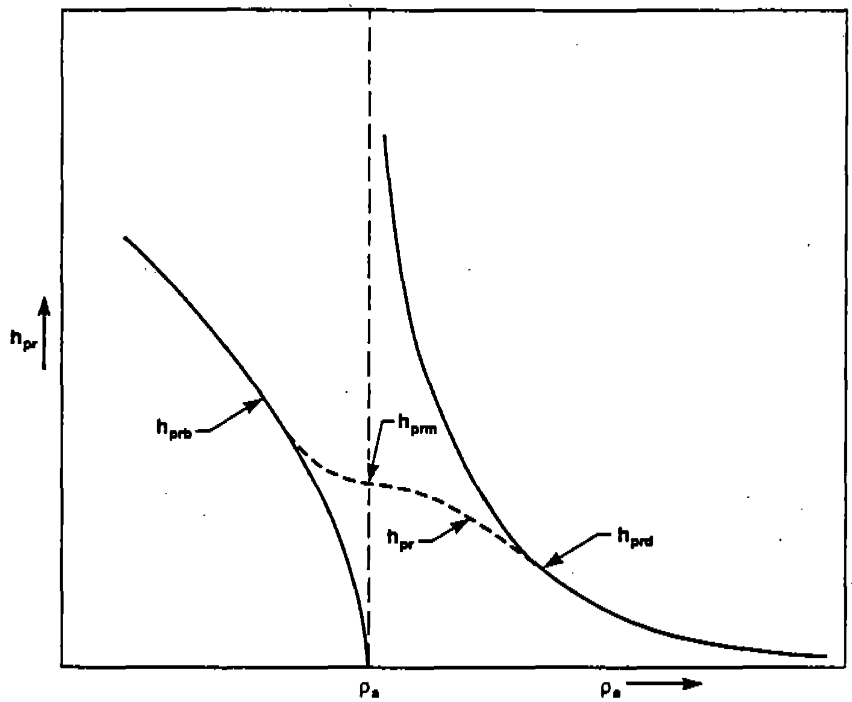

Figure 7. A sketch of plume rise as a function of the source density ρ_s for the following formulas: h_{prb}—Eq. (46c) for the buoyant jet; h_{prd}—Eq. (45a) for the dense-gas jet; h_{prm}—Eq. (46b) for the momentum jet; and h_{pr}— the interpolated value given by Eq. (47).

momentum ($\rho_s = \rho_a$) jet. Unfortunately, this is not the case for the plume rise formulas presented in this section as shown in Fig. 7.

For the buoyant jet where plume rise is given by Eq. (46c), plume rise approaches zero as ρ_s approaches ρ_a. For the case of the dense-gas jet where plume rise is given by Eq. (45a), plume rise approaches infinity as ρ_s approaches ρ_a. To overcome these difficulties the following interpolation formulas are used. When $\rho_s < \rho_a$, plume rise h_{pr} is given by

$$h_{pr} = (h_{prb}^2 + h_{prm}^2)^{1/2} \quad , \tag{47a}$$

where h_{prb} is the plume rise given by the buoyant jet formula of Eq. (45a) and h_{prm} is the plume rise given by the momentum ($\rho_s = \rho_s$) jet formula of Eq. (46b). When $\rho_s > \rho_a$, plume rise is given by

$$h_{pr} = h_{prd} \cdot h_{prm}/(h_{prd}^2 + h_{prm}^2)^{1/2} \quad , \tag{47b}$$

where h_{prd} is the plume rise given by the dense-gas jet formula of Eq. (46c). As can be seen in Fig. 7, these interpolation formulas yield a plume rise value that is consistent with the arguments presented above.

2.6 Time-averaged Concentration

2.6.1 Ensemble, spatial, and time averages

As is generally the case with most atmospheric dispersion models, all of the SLAB results (concentration, cloud width, etc.) represent ensemble averages. An ensemble average is an average over numerous experiments conducted under the same conditions. In a dispersion experiment these conditions are the spill, terrain (surface roughness), and meteorological conditions. Since the model predicted concentration is an ensemble average, it may be greater than or less than the measured concentration from any one experiment. This situation is depicted in Fig. 8 where the instantaneous concentration at time t and downwind distance x is compared with the ensemble average.

In addition to the ensemble average, the SLAB model uses two other types of averages: spatial averages and time averages. Spatial averages are used in the dispersion equations to simplify the equations and, thereby, make them easier to solve. In the steady state plume dispersion mode, crosswind averaging is used to produce differential equations which depend on only the downwind distance. In the transient puff dispersion mode, volume averaging is used to produce differential equations which depend on only time. These one-dimensional differential equations can be rapidly solved numerically in comparison to two- and three-dimensional equations. However, most users require the concentration at a particular location rather than the spatially-averaged concentration. Consequently, in SLAB, the spatially-averaged concentration is converted back to a three-dimensional concentration distribution through the use of similarly profile functions (see Section 2.3). These functions give the concentration distribution about the cloud center and are based on the calculated cloud width, height, and length.

The final average used in SLAB is the time average, which is an average taken at a particular location (x, y, z) over a duration of time t_{av}. (In SLAB t_{av} is called the concentration averaging time.) The reason for time averaging is that safety levels for hazardous chemicals are generally expressed as a maximum allowable average concentration level for a given time of exposure. Typically, exposure times of interest range from a few seconds to minutes and hours. As the exposure time increases, the allowable maximum average concentration decreases. More than one exposure time may need to be considered for any one substance depending upon whether the release is chronic or acute.

In SLAB, the concentration averaging time t_{av} is an input parameter and is used in the time-averaging calculation. Calculation of the time average is generally a rather straightforward procedure. However, in the case of a dispersing cloud in the atmosphere, this calculation is somewhat complicated by the presence of cloud meander as will be discussed in the following section.

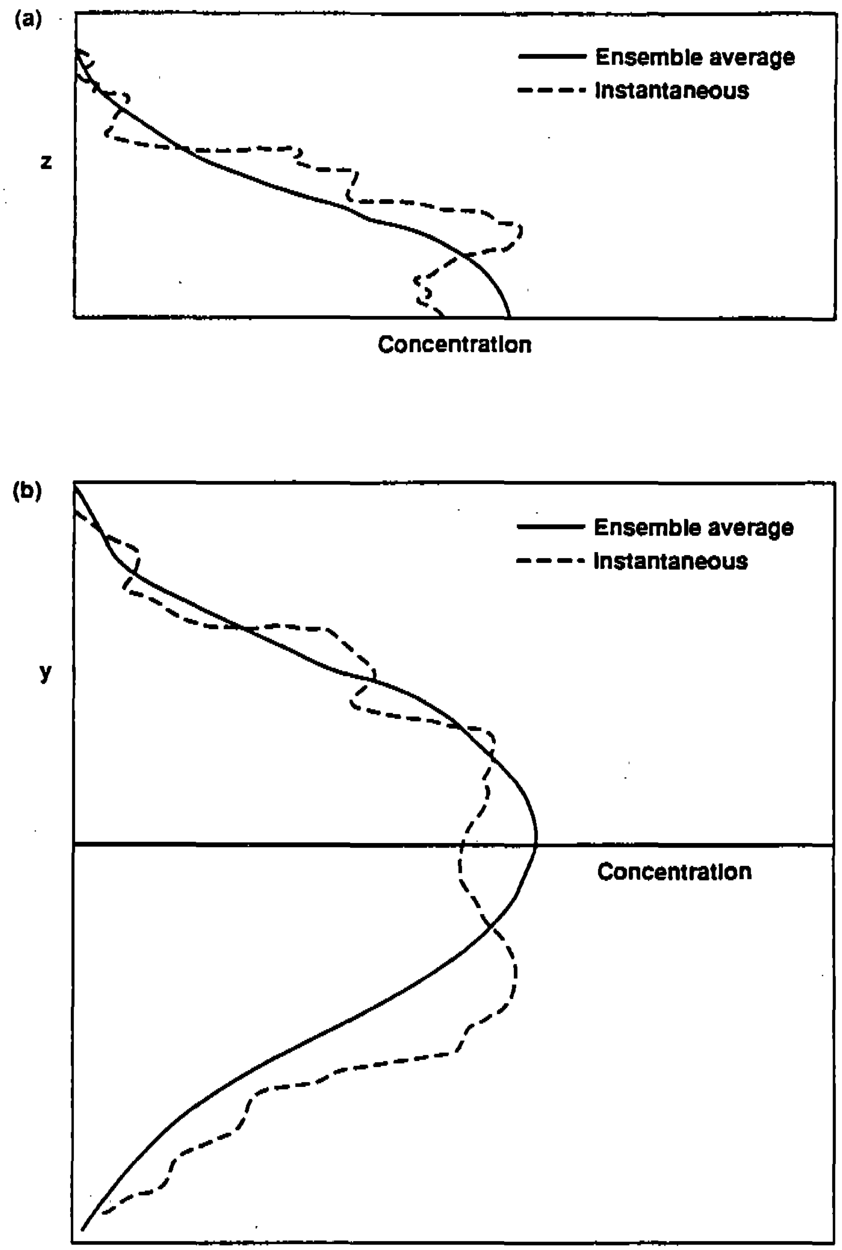

Figure 8. Comparison of the instantaneous concentration at time t with the ensemble average; (a) vertical profile and (b) horizontal profile.

2.6.2 Cloud meander

Cloud meander is the random oscillation of the cloud centerline about the mean wind direction as shown in Fig. 9. When the cloud concentration is averaged over time, the effective width of the cloud appears to be wider as a result of the wandering of the cloud centerline. In addition, the mean cloud concentration decreases in the region about the mean centerline. Empirically it has

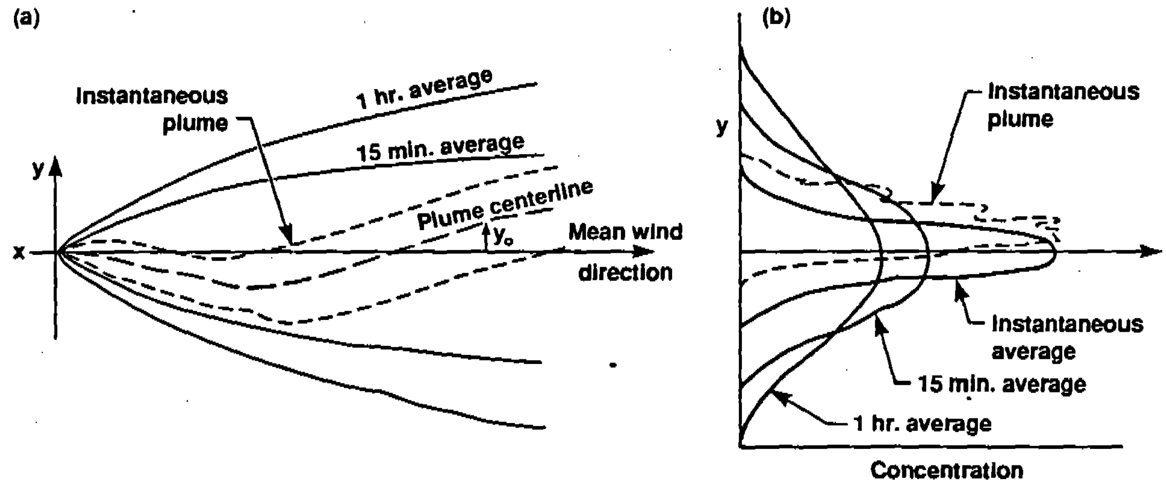

Figure 9. A comparison of the instantaneous plume with several time averages; (a) the plume as observed from above and (b) the crosswind concentration distribution.

been found that the effective width of the cloud increases as the concentration averaging time is increased, also illustrated in Fig. 9.

In the SLAB code solution to the dispersion equations (conservation equations, ideal gas law, and the cloud length and width equations), cloud meander is ignored and the cloud is assumed to travel in a straight line. Consequently, in terms of time-averaging, these results are the "instantaneous" average obtained in the absence of cloud meander. To include the effects of cloud meander associated with longer concentration averaging times, the "instantaneous" average cloud width needs to be modified to include the increase in cloud width due to the displacement y_o (see Fig. 9) of the meandering cloud centerline about the mean wind direction.

One measure of cloud meander is σ_θ, the standard deviation in the horizontal wind direction. Slade (1968) suggests the following relationship for σ_θ for two different averaging times, t_1 and t_2,

$$\sigma_\theta(t_2) = \left(\frac{t_2}{t_1}\right)^{0.2} \cdot \sigma_\theta(t_1) \ . \tag{48}$$

Thus, σ_θ is a slowly increasing function of the averaging time. If it is assumed that the standard deviation $\langle y^2\rangle^{1/2} = \sigma_{pc}$ of a point source Gaussian plume behaves in the same manner, then

$$\sigma_{pc}(t_2) = \left(\frac{t_2}{t_1}\right)^{0.2} \cdot \sigma_{pc}(t_1) \quad . \tag{49a}$$

Modifying this equation at small times so that $\sigma_{pc}(t)$ does not go to zero as t approaches zero, the following equation is obtained

$$\sigma_{pc}(t_{av}) = \left[\frac{t_{av} + \tau_o \cdot \exp(-t_{av}/\tau_o)}{\tau_o}\right]^{0.2} \cdot \sigma_{pc} = r(t_{av}) \cdot \sigma_{yo} \quad , \tag{49b}$$

where t_{av} is the concentration averaging time, τ_o is the effective minimum averaging time, and σ_{yo} is the "instantaneous" plume standard deviation of a trace emission in the absence of cloud meander. A value of $\tau_o = 10$ s is used in SLAB and was found to give good results in comparisons with "instantaneous" measured concentrations from LNG dispersion experiments (Ermak et al., 1982) and to be in general (10%) agreement with the estimates of σ_y given by Petersen (1982) for trace gas puff releases.

The standard deviation $\sigma_{pc}(t_{av})$ of the cloud width is the result of two processes; namely, turbulent diffusion within the cloud σ_{yo} and meander σ_m of the cloud centerline y_o. Assuming that the statistical properties of the cloud meander are governed by a Gaussian distribution, then

$$\sigma_{pc}^2(t_{av}) = \sigma_{yo}^2 + \sigma_m^2(t_{av}) \quad . \tag{50a}$$

Thus, the contribution to the cloud width due to meander is

$$\sigma_m^2(tav) = \left(r_{(t_{av})}^2 - 1\right) \cdot \sigma_{yo}^2 \quad . \tag{50b}$$

This equation, along with the definition of $r(t_{av})$ and σ_{yo}, define the statistical properties of the meandering of the cloud centerline y_o. The averaging parameter $r(t_{av})$ is defined by Eq. (43b) and the "instantaneous" plume standard deviation σ_{yo} can be obtain from the solution to the horizontal crosswind entrainment rate equation Eq. (36a) under ambient conditions,

$$\sigma\prime_{yo} = \frac{a_1}{1 + a_2 \cdot \sigma_{yo}/2a_1} \quad , \tag{51a}$$

where a_1 is a function of the atmospheric stability and $a_2 = 0.0004$ [see Eq. (36a)]. The solution is

$$\sigma_{yo} = (2a_1/a_2) \cdot \left[(1 + a_2 \cdot x)^{1/2} - 1\right] \quad . \tag{51b}$$

These results can now be used to determine the effective cloud width for the error function distribution used by SLAB to describe the horizontal crosswind distribution of the cloud. The time-averaged horizontal crosswind distribution function $C_m(t_{av})$ in terms of the "instantaneous" horizontal crosswind distribution function $C_1(y - y_o, b, \beta)$, Eq. (13), and the increase due to cloud meander $\sigma_m(t_{av})$ is

$$C_m(t_{av}) = \frac{1}{(2\pi)^{1/2}\sigma_m} \cdot \int_{-\infty}^{\infty} dy_o \cdot \exp\left(\frac{-y_o^2}{2\sigma_m^2}\right) \cdot C_1(y - y_o, b, \beta) = C_1(y, b, \beta_c) \quad , \tag{52a}$$

where

$$\beta_c^2 = \beta^2 + \sigma_m^2(t_{av}) \quad . \tag{52b}$$

Thus, the horizontal crosswind distribution function with meander included has the same functional form as before, only the value of β is increased to β_c, and, therefore the effective half-width B_c is increased as a result of cloud meander to

$$B_c^2 = b^2 + 3 \cdot \left[\beta^2 + \sigma_m^2(t_{av})\right] \quad . \tag{53}$$

Similarly, the three-dimensional concentration distribution $C(x, y, z)$ with cloud meander has the same functional form as given by Eq. (13), only $C_1(y, b, \beta)$ is replaced with $C_1(y, b, \beta_c)$. This also holds for the puff mode, where the three-dimensional concentration distribution is given by Eq. (28) and $C_1(y, b_y, \beta_y)$ is replaced by $C_1(y, b_y, \beta_{yc})$. Since the possibility of meander is limited by the duration of the puff, or equivalently, by the length of the puff, the averaging time t_{av} used in the calculation of β_{yc} [Eq. (52b)] is limited by the cloud duration $t_{cd} = 2 \cdot B_x/U$, that is $t_{av} \leq t_{cd}$. Thus, a long puff meanders like a finite length plume, while a short puff has essentially no meander.

2.6.3 Time-averaged volume concentration

With the determination of the effective cloud half-width for the concentration averaging time t_{av}, the calculation of the time-averaged cloud properties is easily accomplished. In SLAB, the only calculated time-averaged property is the volume concentration expressed as the volume fraction with values from 0.0 to 1.0. The time-averaged volume concentration C_{tav} is determined by averaging the cloud volume concentration $C(x, y, z, t)$ (including meander effects) over time as follows

$$C_{tav} = \frac{1}{t_{av}} \int_{t_{pk}-\frac{1}{2}\cdot t_{av}}^{t_{pk}+\frac{1}{2}\cdot t_{av}} dt \cdot C(x, y, z, t) \quad , \qquad (54a)$$

where t_{pk} is the time of peak concentration.

In the steady state plume region, this is rather straightforward since the concentration is assumed to rapidly rise to a steady state value, remain at this value for the duration of the spill t_{sd}, and then rapidly decrease to zero. Thus, the concentration signal in this region is essentially a square-wave in time and the time-averaged concentration C_{tav} is given by

$$C_{tav}(x, y, z) = 2 \cdot B \cdot h \cdot F_{sw} \cdot C(x) \cdot C_1(y, b, \beta_c) \cdot C_2(z, Z_c, \sigma) \quad , \qquad (55a)$$

where

$$F_{sw} = \begin{cases} t_{sd}/t_{av} \ ; & t_{sd} < t_{av} \\ 1 \ ; & t_{sd} > t_{av} \end{cases} \quad ,$$

C, C_1, C_2, B, h, b, Z_c, and σ are all used in Eq. (13) and β_c is given by Eq. (52b).

The calculation of the time-averaged volume concentration in the transient puff dispersion mode is somewhat more complicated. However, the time-averaging integral in Eq. (54a) can be considerably simplified by converting it to an integral over downwind distance x' with the cloud center-of-mass located at the downwind distance of interest $x = X_c(t_{pk})$. Then

$$C_{tav} = \frac{1}{U \cdot t_{av}} \int_{X_c-\frac{1}{2}\cdot U\cdot t_{av}}^{X_c+\frac{1}{2}\cdot U\cdot t_{av}} dx' \cdot C(x', y, z, t_{pk}) \quad , \qquad (54b)$$

where U, X_c, b_x and β_x are all calculated at time $t = t_{pk}$. (In the puff dispersion mode, the time t_{pk} of peak concentration is the arrival time of the puff center-of-mass X_c at the downwind location

x.) With some manipulation, this integral can be evaluated analytically producing the following result for the time-averaged concentration

$$C_{tav}(x = X_c(t_{pk}), y, z, t_{pk}) = 4 \cdot B_x \cdot B_y \cdot h \cdot C(t_{pk}) \cdot C_3(b_x, \beta_x, t_{av}) \cdot C_1(y, b_y, \beta_{yc}) \cdot C_2(z, Z_c, \sigma) \quad , \tag{55b}$$

where

$$C_3(b_x, \beta_x t_{av}) = \left[\beta_x / \left(\sqrt{2} \cdot b_x \cdot U \cdot t_{av}\right)\right] \cdot \left\{x_1 \cdot \mathrm{erf}\ (x_1) - x_2 \cdot \mathrm{erf}\ (x_2) + \frac{1}{\sqrt{\pi}} \left[\exp\left(-x_1^2\right) - \exp\left(-x_2^2\right)\right]\right\} \quad ,$$

$$x_1 = \left(b_x + 1/2 \cdot U \cdot t_{av}\right) / \sqrt{2} \cdot \beta_x \quad ,$$

$$x_2 = \left(b_x - 1/2 \cdot U \cdot t_{av}\right) / \sqrt{2} \cdot \beta_x \quad .$$

C, C_1, C_2, B_x, B_y, h, b_x, β_x, b_y, Z_c, and σ are all as used in Eq. (28), and β_{yc} is given by Eq. (52b).

3. USER'S GUIDE

A standard Fortran 77 version of SLAB is available on 5.25 inch, 360 kilo-byte floppy disk. The files included on the disk are: the Fortran source file, the executable file, and the input and output files for several test problems. The executable file has been compiled with the Microsoft Fortran 4.0 compiler for use on an IBM-AT compatible personal computer.

To run the executable file, the user types and enters the word "SLAB." No additional commands are given by the user. The program looks for a file named INPUT containing the problem input parameters. This input file (INPUT) must exist and be so named prior to execution or a run-time error will be encountered. A SLAB problem can consist of a single SLAB run or several SLAB runs where the meteorological conditions are varied from run to run but the remainder of the spill scenario is kept the same. Consequently, in order to simulate a variety of spill scenarios, separate problems (separate input files) must be designed. When running multiple problems, the name of the input file for each problem must be changed to INPUT prior to executing each individual problem.

After execution, the output is placed in a file named PREDICT. This file contains the output from a single problem which may include one or more SLAB runs as explained above. Again when running multiple problems, care must be taken to change the name of the output file before running the next problem so that an error is not encountered or the new output does not overwrite the previous output file. Examples of the output file, which includes a list of the problem input, are given in the following section.

3.1 Input File

There are 30 possible input parameters required to run SLAB. These parameters include the source type, source properties, spill properties, field properties, the meteorological parameters, and a numerical substep parameter. Only the inverse Monin-Obukhov length (ALA) is optional as described below. Together, these input parameters uniquely define the problem to be simulated. Table 1 identifies each input parameter in the order it is to be listed in the input file and also gives the appropriate units to be used. [SLAB uses the International System of Units. For a reference, see Page and Vigoureux (1972).] The first two input parameters (IDSPL and NCALC) use an I5 integer format. The remaining input parameters all use a floating point format with 10 characters including the decimal point. Thus, the smallest, non-zero, positive entry is .000000001 and the largest, positive entry is 999999999. Below, the input parameters are described more fully with additional comments on their selection.

Table 1. Definition of input variables.

Source Type and Numerical Substep Parameter		
—IDSPL	Spill source type 1—evaporating pool release 2—horizontal jet release 3—vertical jet or stack release 4—instantaneous or short duration evaporating pool release	
—NCALC	Numerical substep parameter	
Source Properties		
—WMS	Molecular weight of source material (KG)	
—CPS	Vapor heat capacity at constant pressure (J/KG-°K)	
—TBP	Boiling point temperature (°K).	
—CMEDO	Initial liquid mass fraction	
—DHE	Heat of vaporization (J/KG)	
—CPSL	Liquid heat capacity (J/KG-°K)	
—RHOSL	Liquid density of source material (KG/M3)	
—SPB	Saturation pressure constant (Default: SPB = -1.0)	
—SPC	Saturation pressure constant (Default: SPC = 0.0)	
Spill Parameters		
—TS	Temperature of source material (°K)	
—QS	Mass source rate (KG/S)	
—AS	Source area (M2)	
—TSD	Continuous source duration (S)	
—QTIS	Instantaneous source mass (KG)	
—HS	Source height (M)	
Field Parameters		
—TAV	Concentration averaging time (S)	
—XFFM	Maximum downwind distance (M)	
—ZP(I)	Heights of concentration calculation (M); I = 1, 4	
Meteorological Parameters		
—ZO	Surface roughness height (M)	
—ZA	Ambient measurement height (M)	
—UA	Ambient wind speed (M/S)	
—TA	Ambient temperature (°K)	
—RH	Relative humidity (percent)	
—STAB	Stability class values	

Class	Value	Description
A-F	1.0–6.0	Unstable-Stable
Default	0.0	Input "ALA" for stability

—ALA	Inverse Monin-Obukhov length (1/M) (ALA is an input parameter only when STAB = 0.0)

3.1.1 Source type and numerical substep parameter

3.1.1.1 IDSPL — Spill source type

SLAB treats four types of sources and these are identified by the integers 1 to 4 as follows:

1—evaporating pool release,

2—horizontal jet release,

3—vertical jet or stack release, and

4—instantaneous or short duration evaporating pool release.

The evaporating pool release is a ground-level, area source of finite duration TSD. The center of the source is located at $x = 0.0$, $y = 0.0$, and $z = 0.0$; where x is downwind distance, y is crosswind distance and z is height. When the spill duration is sufficiently short, a steady state plume does not form at any downwind distance. When the code determines that this is the case, it will automatically stop the calculation, redefine the source type as a "short duration evaporating pool release" (IDSPL = 4), and start the calculation over. This change in source type is shown in the output by a second listing of the initial problem parameters with the spill type (IDSPL) changed from "1" to "4" in the second listing.

The horizontal jet release is an area source with the source plane perpendicular to the ambient wind direction and source velocity pointing directly downwind. The center of the jet is located at $x = 1.0$, $y = 0.0$, and $z =$ HS. The initial mass concentration (mass fraction) is 1.0 with the initial liquid mass fraction specified by the input parameter CMEDO and therefore, the initial vapor mass fraction is given by 1.0 − CMEDO.

The vertical jet or stack release is an area source with the source plane parallel to the ground and the source velocity pointing directly upward. The center of the source is located at $x = 0.0, y = 0.0$, and $z =$ HS. The initial mass concentration (mass fraction) is 1.0 with the initial liquid mass fraction specified by the input parameter CMEDO and therefore, the initial vapor mass fraction is equal to 1.0 − CMEDO.

The instantaneous or short duration evaporating pool release is a combination of two sources: an instantaneous volume source with a total mass given by the input parameter QTIS and a short duration, ground-level, area source with a source rate, and spill duration given by the input parameters QS and TSD, respectively. When an instantaneous volume release is to be simulated, QTIS is specified and QS and TSD are set equal to zero. In the SLAB code, the pressure within the cloud is always equal to $P_A = 101325\ \mathrm{N/m^2} = 1$ atm. Consequently, if an expanding source release (explosion) is to be simulated, the SLAB calculation begins after the source is fully expanded and the pressure has been reduced to the ambient atmospheric level. The short duration evaporating pool release is intended to be a default for the evaporating pool release (IDSPL = 1) when the spill duration is so short that steady state is not reached anywhere within the dispersing cloud. While this type of source can be run directly by setting IDSPL = 4 and specifying QS and TSD, it is recommended that an evaporating pool release of any finite duration be run with the source type parameter IDSPL = 1. If a steady state cloud is not achieved (due to a short spill duration), the code will automatically change the source type to a "short duration evaporating pool" (IDSPL = 4) and indicate this change in the code output as described above.

3.1.1.2 NCALC—Numerical substep parameter

The parameter NCALC is an integer substep multiplier that specifies the number of calculational substeps performed during the integration of the conservation equations. A value of NCALC = 1 is generally recommended to provide computational stability and sufficient numerical accuracy. However, if numerical stability problems are encountered, the value of NCALC can be increased. A value of NCALC = 2 doubles the number of substeps and decreases the size of the integration step by a factor of one-half; a value of NCALC = 3 triples the number of substeps and decreases the size of the integration step by a factor of one-third; etc. The effect of NCALC on the computer run time of a particular simulation is to roughly increase the time by a factor equal to the value of NCALC.

3.1.2 Source properties

3.1.2.1 WMS—Molecular weight of the source material (kg)

3.1.2.2 CPS—Vapor heat capacity at constant pressure (J/kg-°K)

3.1.2.3 TBP—Boiling point temperature of source material (°K)

3.1.2.4 CMEDO—Initial liquid mass fraction

The emission is assumed to be the pure substance with a fraction (CMEDO) in the liquid phase in the form of liquid droplets and the remainder (1.0 – CMEDO) in the vapor phase. Evaporating pool sources are pure vapor (CMEDO = 0.0), while the jet and instantaneous sources may include a liquid fraction. A liquid droplet-vapor mixture is assumed to form when the material is stored as a liquid under pressure at a temperature T_{st} above the boiling point temperature TBP and the material is rapidly released due to a rupture of the container. These temperatures can be used to estimate the mass fraction in the liquid phase using the equation

$$\mathrm{CMEDO} = 1.0 - \mathrm{CPSL} \cdot (T_{st} - \mathrm{TBP})/\mathrm{DHE} \quad ,$$

where CPSL is the specific heat of the material in the liquid phase and DHE is the heat of vaporization at the boiling point temperature TBP.

If the storage temperature T_{st} is less than or equal to the boiling point temperature TBP, the released material will be pure liquid and will presumably form a liquid pool on the ground. In this case, it is suggested that the source type be changed to an evaporating pool release (IDSPL = 1), the liquid mass fraction be set to zero (CMEDO = 0.0), and the area of the evaporating liquid pool be specified by the input parameter AS. Using these inputs, the code will calculate the effective evaporation rate WS from the liquid pool to be

$$\mathrm{WS} = \frac{\mathrm{QS}}{\mathrm{RHOS} \cdot \mathrm{AS}} \quad ,$$

where QS is the input mass source rate, AS is the input source area, and RHOS is the code-calculated vapor density at the boiling point temperature TBP.

3.1.2.5 DHE—Heat of vaporization at the boiling point temperature (J/kg)

3.1.2.6 CPSL—Liquid specific heat of the source material (J/kg–°K)

3.1.2.7 RHOSL—Liquid density of the source material (kg/m³)

3.1.2.8 SPB, SPC—Saturation pressure constants

The saturation pressure constants are used by SLAB in the following expression for the saturation pressure

$$P_{SAT} = P_A \cdot \exp\left[\mathrm{SPA} - \mathrm{SPB}/(\mathrm{T} + \mathrm{SPC})\right] \quad ,$$

where P_A is the ambient pressure (which in SLAB is always taken to be $P_A = 101325\ \mathrm{N/m^3} =$ 1 atm), SPA is defined in the code, and T is the local cloud temperature in °K. When the saturation pressure constants are not known, a default option is available and can be used by specifying the value of SPB to be "–1.0" and the value of SPC to be "0.0". The code will then use the Clapeyron equation to define the value of SPB.

When the source is pure vapor (CMEDO = 0.0) and the temperature of the cloud does not drop below the boiling point temperature, the saturation pressure default option is always adequate since neither the saturation pressure constants nor any of the liquid properties will be used in the SLAB calculation. *However, a value for all of these properties must be specified in the input file whether they are expected to be used or not.*

Values of material properties can be found in a number of references including Reid, Prausnitz, and Sherwood (1977) and Braker and Mossman (1980). Care must be exercised to ensure that the appropriate units for running SLAB are used. Table 2 lists recommended values for the properties of a limited number of materials in the appropriate units to be used in the SLAB code.

Table 2. Material properties in SI units for use in the SLAB code (see text for definition of parameters).

Name	Formula	WMS (kg)	CPS (J/kg-°K)	TBP (°K)	DHE (J/kg)	CPSL (J/kg-°K)	RHOSL (kg/m^3)	SPB —	SPC °K	γ —
Methane	CH_4	.016043	2240.	111.66	509880.	3349.	424.1	597.84	−7.16	1.305
Ethane	C_2H_6	.030070	1774.	184.52	489360.	—	546.5	1511.42	−17.16	1.192
Vinyl Cloride	C_2H_3Cl	.062499	857.7	259.35	357290.	1255.	972.	1803.85	−43.15	—
Ethylene Oxide	C_2H_4O	.044054	1121.	283.66	579450.	1954.	872.	2507.61	−29.01	—
Propylene	C_3H_6	.042081	1482.	225.45	437680.	2176.	513.9	1807.55	−26.15	1.154
Propane	C_3H_8	.044097	1678.	231.09	425740.	2520.	500.5	1872.46	−25.16	1.142
Phosgene	$COCl_2$	.098916	583.3	280.71	246680.	1017.	1371.4	2167.33	−43.15	—
Chlorine	Cl_2	.070906	498.1	239.10	287840.	926.3	1574.	1978.34	−27.01	1.308
Hydrogen Cyanide	HCN	.027026	1444.	298.85	933000.	2608.	679.7	2585.80	−37.15	1.31
Hydrogen Fluoride	HF	.020006	1450.	292.67	373200.	2528.	957.	3404.51	+15.06	—
Hydrogen Sulfide	H_2S	.034076	1004.	212.81	547980.	2010.	960.	1768.71	−26.06	1.33
Ammonia	NH_3	.017031	2170.	239.72	1370840.	4294.	682.8	2132.52	−32.98	1.307
Nitrogen Tetroxide	N_2O_4	.092011	796.5	294.30	414250.	1540.	1446.9	4141.29	+3.65	—
Sulfur Dioxide	SO_2	.064063	622.6	263.13	386500.	1331.	1462.	2302.35	−35.97	1.29

3.1.3 Spill parameters

3.1.3.1 TS—Temperature of the source material (°K)

The definition of the source temperature (TS) depends upon the type of release. When the release is an evaporating pool (IDSPL = 1 or 4), the source temperature is the boiling point temperature TBP. When the release is instantaneous (IDSPL = 4), the source temperature is either the temperature of the material at the instant it is released, or when the source is the result of an explosion, it is the temperature of the material after it is fully expanded and reduced to a pressure of one atmosphere.

The situation is similar for a pressurized jet release (IDSPL = 2 or 3) in that the source conditions are the properties of the material after it has fully expanded. When the source material is stored as a ***vapor*** under pressure and, therefore released as a vapor (CMEDO = 0.0), it is recommended that the expansion be treated as adiabatic. The source temperature is then given by

$$\mathrm{TS} = (1/\gamma) \cdot [1 + (\gamma - 1) \cdot (P_a/P_{st})] \cdot T_{st} \quad ,$$

where $\gamma = C_p/C_v$ is the ratio of specific heats, P_a is the ambient atmospheric pressure, and P_{st} and T_{st} are the storage pressure and temperature, respectively. If the calculated source temperature (TS) for a vapor release is below the boiling point temperature (TBP), then the source temperature should be set equal to the boiling point temperature. Similarly, when the source material is stored as a ***liquid*** under pressure and released as a two-phase liquid droplet-vapor mixture, the source temperature is the boiling point temperature TBP.

The temperature of the source material (TS) must be equal to or greater than the boiling point temperature TBP since the source is either totally in the vapor phase (TS $\geq$ TBP) or a mixture of liquid droplets and vapor at equilibrium (TS = TBP). The code checks the input source temperature and ensures that the above conditions are met. If the source temperature is less than the boiling point temperature (TS < TBP), then the source temperature is reset equal to the boiling point temperature (TS = TBP). Furthermore, if the release is a liquid-vapor mixture (CMEDO > 0.0), then the spill temperature is automatically set equal to the boiling point temperature (TS = TBP). When the code changes the source temperature value, the change can be observed in the code output by comparing the input value listed under "PROBLEM INPUT" and the value used by the code as listed under "RELEASE GAS PROPERTIES."

3.1.3.2 QS—Mass source rate (kg/s)

This is the mass source rate for any of the continuous sources; namely, an evaporating pool release (IDSPL = 1), either of the jet releases (IDSPL = 2 or 3), and the short duration evaporating pool (IDSPL = 4). For an instantaneous release (IDSPL = 4), the mass source rate should be set equal to zero (QS = 0.0).

3.1.3.3 AS—Source area (m^2)

The source area has different definitions depending upon the type of release. For an evaporating pool release (IDSPL = 1 or 4), AS is the area of the evaporating pool. If AS is not known it can be calculated from the effective evaporation rate (regression rate) WS using the identity

$$\mathrm{AS} = \frac{\mathrm{QS}}{\mathrm{RHOS} \cdot \mathrm{WS}} \quad ,$$

where QS is the input mass source rate, RHOS is the vapor density of the source material at the boiling point temperature TBP, and WS is the known evaporation rate expressed as a velocity (m/s). The vapor density RHOS is given by the ideal gas law and is

$$\mathrm{RHOS} = (\mathrm{WMS} \cdot P_a)/(R_c \cdot \mathrm{TBP}) \quad ,$$

where WMS is the input molecular weight of the source material, P_a is the ambient atmospheric pressure ($P_a = 101325.\ \mathrm{N/m^3}$), R_c is the gas constant [$R_c = 8.31431\ \mathrm{J/(mol{-}^\circ K)}$], and TBP is the input boiling point temperature.

When the source is a pressurized horizontal or vertical jet release (IDSPL = 2 or 3), AS is the area of the source after it has fully expanded and the pressure is reduced to the ambient level. If the source material is stored and released as a pure ***vapor*** (CMEDO = 0.0), it is recommended that the expansion be treated adiabatically, as discussed in Section 3.1.3.1. The source area can then be expressed as

$$\mathrm{AS} = (P_{st}/P_a) \cdot (\mathrm{TS}/T_{st}) \cdot A_r \quad ,$$

where P_{st} is the storage pressure, P_a is the ambient atmospheric pressure, TS is the input source temperature, T_{st} is the storage temperature, and A_r is the actual area of the rupture or opening. When the source material is stored as a ***liquid*** under pressure and released as a two-phase jet, AS is the area of the source after it has flashed and formed a liquid droplet-vapor mixture of the pure substance. In this case, the value of AS is given by the formula

$$\mathrm{AS} = \frac{\mathrm{RHOSL} \cdot A_r}{\rho_m} \quad ,$$

where RHOSL is the input liquid density of the source material, A_r is the actual area of the rupture or opening, and ρ_m is the density of the liquid-vapor mixture after flashing and at the boiling point temperature TBP with liquid mass fraction CMEDO. The value of ρ_m can be calculated from the equation of state and with some rearranging of terms is given by

$$\rho_m = 1 \Big/ \left[\frac{(1 - \mathrm{CMEDO})}{\mathrm{RHOS}} + \frac{\mathrm{CMEDO}}{\mathrm{RHOSL}}\right]$$

where CMEDO is the input initial liquid mass fraction, RHOSL is the input liquid density of the source material, and RHOS is the vapor density of the source material at the boiling point temperature TBP, as previously given in this section.

In the case of an instantaneous release (IDSPL = 4), AS is the area of the volume source in the ground plane centered on the point $X = Y = Z = 0.0$. The source area is defined to be

$$\mathrm{AS} = \frac{V_s}{\mathrm{HS}} = \frac{\mathrm{QTIS}}{\rho_{si} \cdot \mathrm{HS}} \quad ,$$

where V_s is the volume of the instantaneous release, HS is the height of the volume, QTIS is the input mass of the release, and ρ_{si} is the initial density of the release. When the source is a pure *vapor* release, ρ_{si} is the vapor density of the pure substance at the source temperature TS and is given by

$$\rho_{si} = (\mathrm{WMS} \cdot P_a) \,/\, (R_c \cdot \mathrm{TS}) \quad .$$

When the source is a *liquid-vapor mixture*, ρ_{si} is the mixture density ρ_m (previously given in this section) at the boiling point temperature TBP with liquid mass fraction CMEDO.

3.1.3.4 TSD—Continuous source duration (s)

This parameter specifies the duration of the release from an evaporating pool (ISDPL = 1 or 4) or jet (IDSPL = 2 or 3) source. When an instantaneous release is to be simulated TSD should be set to zero (TSD = 0.0).

3.1.3.5 QTIS—Instantaneous source mass (kg)

This is the total mass of the instantaneous release (IDSPL = 4). For an evaporating pool or jet release, QTIS should be set to zero (QTIS = 0.0).

3.1.3.6 HS—Source height (m)

The definition of the source height differs for each source type. In the case of an evaporating pool release (IDSPL = 1 or 4), HS = 0.0 since the pool is assumed to be at ground level. For a horizontal jet (IDSPL = 2), HS is the height of the jet center, while it is the actual height of the jet or stack in the case of a vertical jet release (IDSPL = 3). When an instantaneous release (IDSPL = 4) is simulated, HS is the height of the instantaneous release, such that, the product of the source height HS and source area AS is equal to the total volume released (see the comments on the source area AS).

3.1.4 Field parameters

3.1.4.1 TAV—Concentration averaging time (s)

The concentration averaging time is the appropriate averaging time for the safety standard of interest. For example, if the safety standard of interest for a particular material is a maximum average concentration of 100 ppm for a 1 hr exposure, then TAV = 3600 s.

For a single toxic material, there are generally a number of safety levels of interest, each corresponding to a different exposure time. Thus, there might be an 8 hr, 1 hr, 15 min, and less than 1 min exposure level. In this case, SLAB would have to be run four times, each with a different value of TAV corresponding to the appropriate duration of exposure.

Care should be exercised when the concentration averaging time TAV is greater than the cloud duration TCD. When TAV $\gg$ TCD, the average concentration will be reduced due to the fact that the puff is relatively short and the observer is exposed to the material for only a fraction of the concentration averaging time TAV. In this case, a more meaningful concentration averaging time to use might be one that is less than or equal to the cloud duration, TAV $\leq$ TCD. The cloud duration TCD is calculated in the code and listed in the output. It is defined to be the ratio of the cloud length to the average cloud velocity,

$$\mathrm{TCD} = \frac{2 \cdot \mathrm{BBX}}{\mathrm{U}} \quad .$$

In the case of a continuous, finite duration release, TCD can be initially approximated by the continuous source duration TSD. When the release is instantaneous or very short, it is difficult to estimate the cloud length and cloud duration, so a comparison of the concentration averaging time TAV and the cloud duration TCD must wait until the SLAB run is completed.

3.1.4.2 XFFM—Maximum downwind distance (m)

This distance is the maximum downwind distance for which the user is interested in knowing the cloud concentration. In the steady state plume dispersion mode, the simulation is conducted to a downwind distance equal to XFFM. However, in the transient puff dispersion mode, time is the independent variable rather than downwind distance. Consequently, in the puff mode the simulation is conducted to a downwind distance that is generally slightly larger than XFFM.

For some applications, XFFM is not know, however, the minimum concentration of interest is known. In this case, an initial SLAB run may have to be made using an estimated value of XFFM to determine the value of XFFM that will cover the concentration range of interest.

3.1.4.3 ZP(I), I = 1, 4—Heights of concentration calculation (m)

There are a maximum of four heights [ZP(I), I = 1, 4] at which the concentration is calculated as a function of downwind distance. All of the values are specified by the user in the input file. If ZP(N), where $2 \leq \mathrm{N} \leq 4$, is set equal to zero [ZP(N) = 0], then the code will calculate the concentration at the heights ZP(I), I = 1 to N–1, rather than I = 1 to 4. However, no matter how many heights are to be used in the concentration calculation, four values of ZP must be specified in the input file even if all four are equal to zero.

3.1.5 Meteorological parameters

3.1.5.1 ZO—Surface roughness height (m)

Surface roughness ZO is generally estimated in one of two ways. The first and usually more reliable method is to extrapolate measured ambient velocity profile data $(U_a(z_i), i = 1, \mathrm{N})$ under neutral stability conditions $[U_a(Z) = (U_*/k) \cdot ln(Z/Z_o)$, k = 0.41 = von Karman constant] back to where $U_a(Z) = 0.0$. This can be done by either a least-squares fit to determine the friction velocity U_* and surface roughness height ZO or by plotting the data on a semi-log plot and linearly extrapolating until $U_a(Z) = 0.0$. Similarly, measured values of U_* and $U_a(Z)$ under neutral conditions can be used to estimate ZO if they are available. The second method uses values of ZO that have been empirically determined for various ground surface conditions, such as those listed in Table 3 taken from Slade (1968). Estimates of ZO for large surface roughness elements such as vehicles and buildings can be made, although it should be noted that the value of ZO depends on the shape and number of the elements per unit area as well as the height of the elements. Typically, the surface roughness elements are a factor of 3 to 20 larger in height than the value of ZO, so a general "rule of thumb" might be to use a factor of 10.

Table 3. Typical values of surface roughness.

Type of surface	Surface roughness, Z_o (cm)
Smooth mud flats; ice	0.001
Smooth snow	0.005
Smooth sea	0.02
Level desert	0.03
Snow surface; lawn to 1 cm high	0.1
Lawn, grass to 5 cm	1–2
Lawn, grass to 60 cm	4–9
Fully grown root crops	14

Caution in interpreting the SLAB results should be exercised when simulations are made using large values of ZO with the release occurring at a height that is comparable to the surface roughness element height or less. Under these conditions, much of the cloud dispersion may take place within the height of the surface roughness elements. However, the empirical validity of the "ln (Z/ZO)" profile for the ambient windspeed has been shown only for heights significantly greater than the surface roughness height, i.e., Z $\gg$ ZO. In SLAB, the velocity profile from Z = 0 to Z = 2.72 $\cdot$ ZO is assumed to be essentially linear with continuity at Z = 2.72 $\cdot$ ZO to the "ln (Z/ZO)" profile. The actual profile may differ considerably depending upon the type, number and arrangement of the actual surface roughness elements. Caution also has to be exercised in the use of the input ambient wind speed measurement UA when the flow extends above the surface roughness elements. In order to be accurate in this regime, the height of the windspeed measurements ZA must be much greater than the surface roughness height, ZA $\gg$ ZO.

3.1.5.2 ZA—Ambient measurement height (m)

This is the height at which the ambient windspeed is measured. As noted above, this height should be significantly larger than the surface roughness length, ZA $\gg$ ZO.

3.1.5.3 UA—Ambient wind speed (m/s)

This is the average ambient wind speed at the height ZA above ground level.

3.1.5.4 TA—Ambient temperature (°K)

3.1.5.5 RH—Relative humidity (percent)

3.1.5.6 STAB—Stability class values

The whole numbers from 1.0 to 6.0 are used in the code to describe the ambient atmospheric stability using the standard Pasquill-Gifford stability scheme as shown below in Table 4. The code will actually accept STAB values from 0.5 to 7.5; however, if the user wants to simulate one of the six Pasquill-Gifford stability classes, the corresponding whole number value from 1.0 to 6.0 must be used.

Table 4. Atmospheric stability scheme.

Class	Value	Description
A	1.0	Very unstable
B	2.0	Unstable
C	3.0	Slightly unstable
D	4.0	Neutral
E	5.0	Slightly stable
F	6.0	Stable
Default	0.0	Input "ALA" for stability

An alternative method for describing atmospheric stability using the Monin-Obukhov length is also available in the code. This is done by using the default value for STAB, namely STAB = 0.0, and then specifying a value for the inverse Monin-Obukhov length ALA.

3.1.5.7 ALA—Inverse Monin-Obukhov length (m^{-1})

The Monin-Obukhov length is a stability parameter used in similarity theory to describe the vertical profile of the ambient wind speed and the vertical turbulent diffusivity (or equivalently, the vertical entrainment rate) as described in Section 2.5. The inverse Monin-Obukhov length ALA is defined to be, $ALA = 1/L_a$, where L_a is the ambient Monin-Obukhov length. This option for describing atmospheric stability is activated by setting STAB = 0.0 and then including the additional input parameter ALA. Furthermore, ALA is an input parameter *only* when STAB = 0.0. Inclusion of ALA as an input parameter when STAB is *not* set equal to zero can result in an execution error.

These two methods for describing atmospheric stability, namely specification of either STAB or ALA, are equivalent within the SLAB code. The code uses the inverse Monin-Obukhov length ALA in its calculations. Consequently, when stability class STAB is specified, it is converted to inverse Monin-Obukhov length. As noted in Section 2.5.2, the relationship between the stability class and Monin-Obukhov length is taken from Golder (1976).

3.1.6 Input file closure

After the code has read the input and executed a run, it returns to the start of the code looking for an additional value of ZO the surface roughness length. If an additional input value of ZO is specified, the code will look for the remaining meteorological input parameters [ZA, UA, TA, RH, STAB, and ALA (if STAB = 0.0)] and execute an additional run with the new meteorological inputs. In this way multiple runs can be made with the same source type and the same source, spill and field properties, but different meteorological conditions.

On the other hand, when the code looks for an additional value of ZO and finds a value less than zero, it terminates the problem. Thus, the problem is terminated by including an additional input parameter with the value "–1.0" (or any value less than zero) at the end of the input file.

3.2 Calculational Flow

A SLAB model simulation can be viewed as occurring in three sequential phases: initialization, dispersion calculation, and time-averaged concentration calculation. The calculational flow starting with the identified source type and ending with the calculation of the time-averaged concentration is shown in Fig. 10.

3.2.1 Initialization

The initialization phase begins with the specification of the source type (Horizontal Jet, Vertical Jet, Evaporating Pool, Instantaneous or Short Duration Release). The type of source is identified in the input file; however, there is one case where the code will override the specified source type.

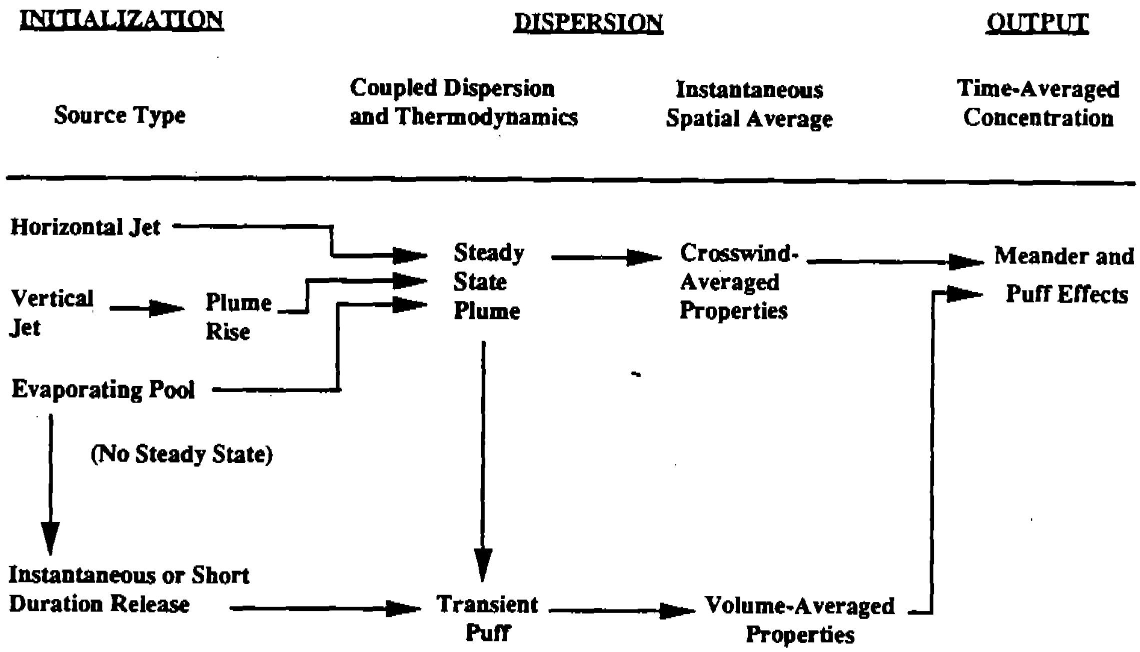

Figure 10. Calculational flow within the SLAB code.

This situation can occur when an Evaporating Pool source is specified (see Fig. 10). The code will override the specified source type when the code determines that the duration of release is so short that a steady state cloud is not reached within the evaporating pool source region. In this case, the source type is switched from an Evaporating Pool source to an Instantaneous or Short Duration Release and the calculation is begun a new. Here, the source is still treated as an evaporating pool; however, the transient puff equations rather than the steady state plume equations are used to calculate cloud dispersion.

The identification of the source type, along with the remainder of the input data and some additional information stored within the code, is used to initialize the SLAB code simulation. With the initialization process completed, the code is ready to begin the dispersion calculation.

3.2.2 Dispersion calculation

The dispersion phase contains the bulk of the calculations. It is here that the coupled conservation equations and the thermodynamics equations are solved yielding the instantaneous (no meander) spatially-averaged properties as a function of downwind distance. As shown in Fig. 10, there are two dispersion modes, a steady state plume mode and a transient puff mode. A sketch of a cloud dispersing in these two modes is given in Fig. 11. The steady state plume mode is used for the finite duration releases until the end of the release. After the release is over, the transient puff mode is used for the remainder of the calculation. The transient puff mode is also used in the

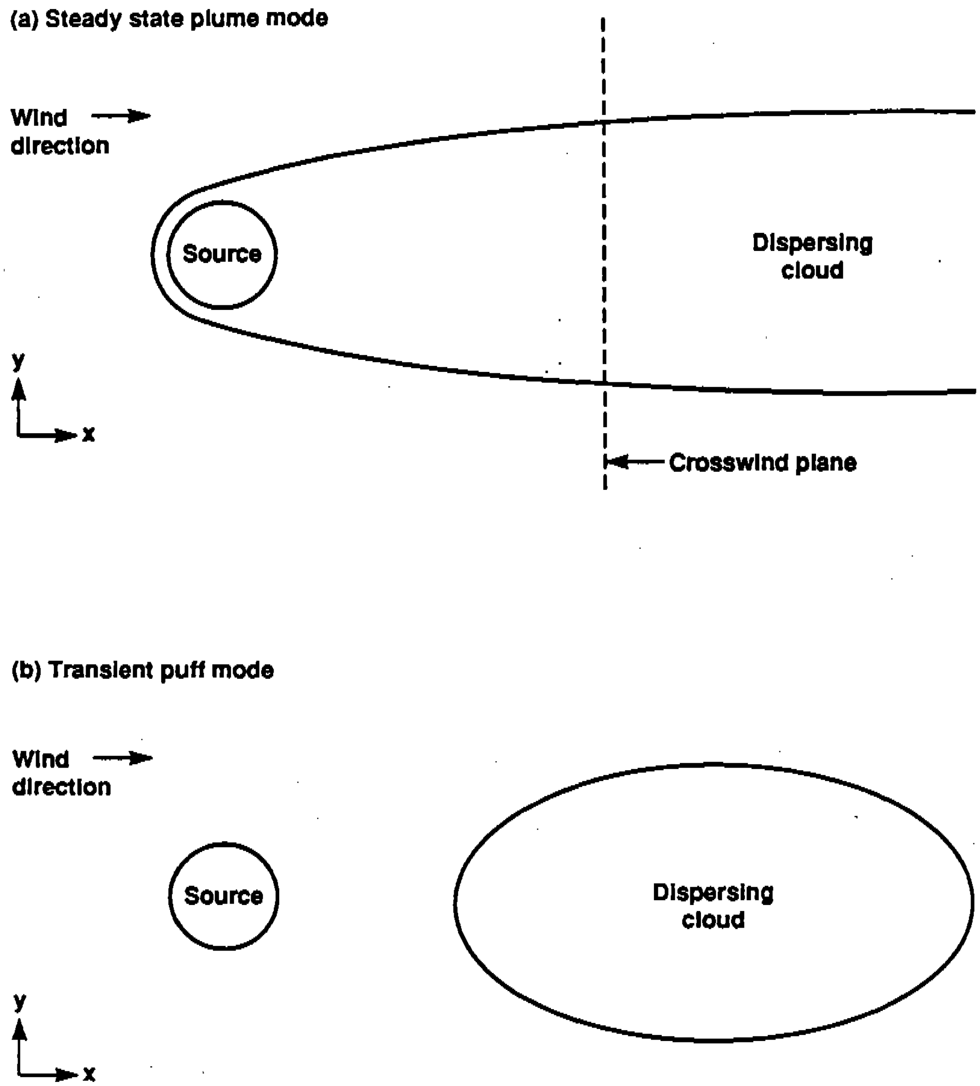

Figure 11. A dispersing cloud in the (a) steady state plume mode and the (b) transient puff mode.

case of an instantaneous release or when the release duration is so short that a steady state is not reached (as described above).

From a mathematical and calculational point of view, these two modes represent two different forms for the conservation equations. In the steady state plume mode, the conservation equations are spatially averaged over the crosswind plane of the cloud (see Fig. 11). Consequently, the resulting cloud properties obtained from the solution of the conservation equations are also spatially averaged over the crosswind plane. Using concentration as an example, the relationship between the concentration $C(x, y, z)$ at the point (x, y, z) and the crosswind-averaged concentration $\overline{C}(x)$

as a function of downwind distance x is given by

$$\overline{C}(x) = \frac{1}{2Bh} \int_0^\infty dz \int_{-\infty}^\infty dy \; C(x,y,z) \quad ,$$

where $B = B(x)$ and $h = h(x)$ are the cloud half-width and height, respectively. Both B and h are calculated along with the solution of the conservation equations (see Section 2.3.1). The crosswind-averaged concentration $\overline{C}$ is not expressed as a function of time since the plume is assumed to be in steady state for the duration of the release.

In the transient puff mode, the conservation equations are averaged over the entire volume of the cloud. Consequently, solution of the conservation equations yields volume-averaged cloud properties. Again using concentration as an example, the relationship between the concentration $C(x,y,z,t)$ at the point (x,y,z) and time t and the volume-averaged concentration $\overline{C}(t)$ is given by

$$\overline{C}(t) = \frac{1}{4BB_xh} \int_o^\infty dz \int_{-\infty}^\infty dy \int_{-\infty}^\infty dx \; C(x,y,z,t) \quad ,$$

where $B = B(t)$, $B_x = B_y(t)$, and $h = h(t)$ are the cloud half-width, half-length, and height, respectively. These parameters $(B, B_x,$ and $h)$ and the cloud center-of-mass $X_c(t)$ are calculated along with the solution of the conservation equations (see Section 2.3.2). By calculating the center of mass $X_c(t)$, the volume-averaged concentration $\overline{C}$ can be expressed as a function of downwind distance $\overline{C}(X_c)$ as well as time $\overline{C}(t)$, or in general $\overline{C} = \overline{C}(X_c(t), t)$.

The choice of dispersion mode is initially dictated by the source type (see Fig. 10). The horizontal and vertical jet and evaporating pool sources all begin the dispersion calculation in the steady state plume mode. The dispersion calculation remains in the steady state plume mode for the duration of the release t_{sd}. After the release is terminated, $t > t_{sd}$, the dispersion calculation is performed in the transient puff mode. Thus, the transition from the steady state plume mode to the transient puff model occurs at the time $t = t_{sd}$ and at the downwind distance x corresponding to the cloud center-of-mass, $x = X_c(t_{sd})$. In the case of the instantaneous or short duration release sources, there is no time period during which the cloud is in steady state. Consequently, the entire dispersion calculation is conducted in the transient puff mode (see Fig. 10).

The approach taken in SLAB to solve the two forms of the dispersion equations (plume and puff) are similar. The main code sets up the integration of the dispersion equations and utilizes five subroutines to carry it out (see Table 5). SLOPE (or SLOPEPF) calculates the rate of change for the conservation equations and SOLVE (or SOLVEPF) integrates them. Using the solutions to the basic conservation equations, THERMO calculates the thermodynamic properties (m, p, T, etc.) and then EVAL (or EVALPF) calculates the transport properties (U, $\overline{U}_a$, h, B, B_x, etc.). The final subroutine STORE, stores the results at regular intervals to be included in the output or used in subsequent calculations.

Table 5. SLAB subroutines used in the dispersion calculations.

Steady State		Puff
SLOPE	(rate of change equations)	SLOPEPF
SOLVE	(integrated dispersion equations)	SOLVEPF
THERMO	(calculates m, ρ, T, etc.)	THERMO
EVAL	(calculates U, $\overline{U}_A$, h, B, B_x, etc.)	EVALPF
STORE	(stores instantaneous spatially-averaged properties)	STORE

3.2.3 Time-averaged concentration calculation

After the spatially-averaged cloud properties are calculated at all downwind distances x of interest, the code calculates the time-averaged concentration. This is the result of primary interest to most code users. In SLAB, the time-averaged concentration is expressed as the volume fraction with values ranging from 0.0 to 1.0. (To convert volume fraction to parts-per-million (ppm), multiply the volume fraction by one million.)

The time-averaged volume fraction $C_{tav}(x, y, z, t)$ is calculated from the spatially-averaged volume fraction $\overline{C}(X_c, t)$ and the cloud height, width, and length parameters. To do this, the concentration distribution about the center-of-mass X_c must be assumed since $\overline{C}(X_c, t)$ does not include this information. The profile distribution functions used in SLAB are described in Sections 2.3.1 and 2.3.2 and are functions of the calculated cloud half-width $B(X_c, t)$, half-length $B_x(X_c, t)$, and height $h(X_c, t)$ and are consistent with the spatially-averaged volume fraction $\overline{C}(X_c, t)$.

The volume fraction $C(x - X_c, y, z, t)$ in three-dimensional space and time is therefore defined in terms of the calculated spatially-averaged volume fraction and the assumed profile distribution function. The calculation of the *time-averaged* volume fraction C_{tav} (x, y, z, t) from the volume fraction $C(x - X_c, y, z, t)$ involves two steps. The first step involves the calculation of the effective cloud half-width B_c (which includes the effects of cloud meander) starting from the "instantaneous" cloud half-width B (where meander effects are assumed to be absent). The second step is the direct calculation of the time-averaged volume fraction using the effective volume fraction $C_m(x - X_c, y, z, t)$ where the "instantaneous" half-width B is replaced with the effective half-width B_c including meander.

The effects of cloud meander, and the method used in SLAB to calculate it, are described in Section 2.6. Essentially, cloud meander increases the effective width of the cloud and thereby reduces the average concentration that is observed in the cloud centerline region. In general, the increase in the effective cloud width depends upon the length of the concentration averaging time t_{av}. The longer the averaging time, the more meander can occur and the greater the increase in the effective width. An exception to this general rule occurs when the averaging time t_{av} is longer than the cloud duration t_{cd} at the downwind distance of interest. The time available for cloud meander t_{mdr} at the downwind location x cannot be longer than the duration of exposure t_{cd} to the cloud at this same location. (The cloud duration is defined to be $t_{cd} = 2 \cdot B_x/U$, where B_x is the cloud half-length and U is the average downwind velocity of the cloud.) Thus, the time available for cloud meander is assumed to be equal to the concentration averaging time $t_{mdr} = t_{av}$ with a maximum value equal to the cloud duration $(t_{mdr})_{max} = t_{cd}$. As a result, the effective width of the cloud increases monotonically with the concentration averaging time t_{av} until some maximum value is reached that is dependent on the length of the cloud.

With the calculation of the effective cloud half-width, the time-averaged volume fraction can now be determined. The form of the concentration distribution function is such that the required integration can be done analytically as described in Section 2.6. Thus, SLAB uses the calculated spatially-averaged mass fraction $\overline{C}(X_c, t)$ along with the time-averaged form of the concentration distribution function to evaluate the time-averaged volume fraction at the downwind location (x, y, z).

The calculation of the time-averaged volume fraction concludes the SLAB run. At this point, the code checks to see if there are additional simulations to be conducted using the same release scenario but different meteorological conditions. If additional simulations are included in the input file, these simulations will be run in the manner described above until all the simulations are completed.

3.3 Output File

The output file contains several types of information which can be grouped into three categories; namely,

- problem description,
- instantaneous spatially-averaged cloud properties, and
- time-averaged volume fraction.

These categories correspond to the three sequential phases (Initialization, Dispersion Calculation, and Time-Averaged Concentration Calculation) of the SLAB code calculation as shown previously in Fig. 10.

3.3.1 Problem description

The Problem Description output lists the various input parameters used by the code and thereby defines the problem to be solved. The first group of parameters is the Problem Input which gives the input parameter values as specified *by the user*. As noted in Section 3.1, a few of the input parameters (IDSPL, SPB, SPC, TS, and STAB) may be changed by the code in order to be consistent with SLAB model assumptions. These changes (if they are made) are reflected in the following parameter listings entitled Release Group Properties, Spill Characteristics, Field

Parameters, Ambient Meteorological Properties, and Additional Parameters. These listings give the parameter values actually used in the simulation. The listed parameters include the input parameters plus additional parameters that describe the spill scenario.

3.3.2 Instantaneous spatially-averaged cloud properties

The Instantaneous Spatially-Averaged Cloud Properties output gives the results of the dispersion calculation phase of the simulation. These results are intermediate results in that they are the solution of the spatially-averaged (Plume or Puff) conservation equations, the equation of state (ideal gas law), and the length and width equations; however, they do not include the effects of cloud meander or time-averaging. Table 6 lists and defines the instantaneous spatially-averaged parameters and identifies the units in which they are given. These parameters are listed in the output as a function of downwind distance (X).

Table 6. Definition of the instantaneous spatially-averaged cloud parameters.

[In the steady state dispersion mode, spatial averaging is over the crosswind plane of the cloud. In the puff dispersion mode, spatial averaging is over the entire volume of the cloud.]

—X	Downwind distance (M)
—ZC	Profile center height (M)
—H	Cloud height (M)
—BB	Cloud half-width (M)
—B	Half-width parameter (M)
—BBX	Cloud half-length (M)
—BX	Half-length parameter (M)
—CV	Volume fraction of emission
—RHO	Density (KG/M3)
—T	Temperature (°K)
—U	Downwind cloud velocity (M/S)
—UA	Height-averaged ambient wind speed (M/S)
—CM	Mass fraction of emission
—CMV	Mass fraction of emission vapor
—CMDA	Mass fraction of dry air
—CMW	Mass fraction of water
—CMWV	Mass fraction of water vapor
—WC	Gravity flow velocity, Z-direction (M/S)
—VG	Gravity flow velocity, Y-direction (M/S)
—UG	Gravity flow velocity, X-direction (M/S)
—W	Vertical entrainment velocity (M/S)
—V	Crosswind horizontal entrainment velocity (M/S)
—VX	Downwind horizontal entrainment velocity (M/S)

The cloud properties listed in this part of the output are described as "instantaneous" and "spatially" averaged properties. As was discussed in Section 2.6, all of the SLAB results are ensemble averages; that is, they represent the average taken over numerous trials under the same conditions. In addition, these ensemble average values can be averaged over time and in space. The term "instantaneous" refers to the time averaging and indicates that the duration of the time period over which the average is taken is essentially zero. Thus, the effects of cloud meander are assumed to be absent in the "instantaneous" average.

The "spatial" averaging used in the SLAB code is of two types: crosswind-averaged and volume-averaged. The choice of "spatial" averaging depends on the dispersion mode (steady state plume mode or transient puff mode) that is used. During a finite duration release (t < TSD), the code generally uses the steady state plume mode for the dispersion calculation and the cloud properties are averaged over the crosswind plane of the plume (see Section 3.2). After the release has terminated (t > TSD), or at all times in the case of an instantaneous or short duration release, the code uses the transient puff dispersion mode and the cloud properties are averaged over the volume of the cloud (see Section 3.2).

When a finite duration release is simulated, a transition occurs in the dispersion calculation as the code switches from the plume to the puff dispersion mode with the transition occurring at the end of the release, t = TSD. Since there is no discontinuity in the actual dispersion of a cloud at this time, the code predicted values should also maintain this continuity. This is done in the SLAB code by the definition of the cloud half-length at the time of the transition in the dispersion mode calculation.

At the time of transition from the plume to the puff mode (t = TSD), the crosswind-averaged (plume) mass fraction CM_c is defined to be

$$CM_c = \frac{\mathrm{QS}}{2 \cdot \mathrm{RHO}_c \cdot U_c \cdot \mathrm{BB} \cdot \mathrm{H}} \quad ,$$

where QS is the mass source rate, RHO_c is the crosswind-averaged cloud density, U_c is the crosswind-averaged downwind velocity, BB is the cloud half-width and H is the cloud height. Similarly, the volume-averaged (puff) mass fraction CM_v is defined to be

$$CM_v = \frac{\mathrm{QS} \cdot \mathrm{TSD}}{4 \cdot \mathrm{RHO}_v \cdot \mathrm{BBX} \cdot \mathrm{BB} \cdot \mathrm{H}} \quad ,$$

where RHO_v is the volume-averaged cloud density and BBX is the puff-half length. By requiring that CM, RHO, and U are all continuous at the transition time t = TSD, the puff half-length BBX is found to be BBX = $0.5 \cdot U \cdot$ TSD. This is the value used in the code for BBX at t = TSD. Consequently, all of the cloud properties are smooth and continuous as the code switches from the steady state plume mode to the transient puff mode.

3.3.3 Time-averaged volume fraction

The primary output of interest for most applications is the time-averaged concentration. In the SLAB output, the time-averaged concentration is expressed as the Time-Averaged Volume Fraction with values ranging from 0.0 to 1.0. (Volume fraction is easily converted to concentration in parts-per-million (ppm) by multiplying the volume fraction by one-million.)

The time-averaged volume concentration output is presented under three sub-titles:

- Concentration Contour Parameters
- Concentration in the Z = ZP(I) Plane
- Maximum Centerline Concentration

All of these results are presented from the viewpoint of an observer or receptor located at the downwind distance x, the crosswind distance y from the mean cloud centerline, and the height z above the ground. From this vantage point, the observer sees the maximum cloud concentration at time t_{pk} and is exposed to the cloud for the time period t_{cd} with half the exposure occurring before t_{pk} and half after. During the averaging time period t_{av} (which is also centered about the time of maximum concentration t_{pk}), SLAB predicts the observer is exposed to an average concentration C_{tav}. Similarly, a second observer located at the downwind distance x', sees the maximum concentration arrive at t'_{pk} and is exposed to the cloud for the time period t'_{cd} with an average concentration C'_{tav} during the time period t_{av}.

The Concentration Contour Parameters output lists a number of parameters from which the time-averaged volume concentration at any downwind location (X, Y, Z) and time (T) within the problem domain can be calculated. The time-averaged volume concentration is given by Eq. (55) and is expressed in the output in the slightly different form of Eqs. (56a) and (56b) for computational convenience.

When the source is either an evaporating pool or jet (horizontal or vertical) source, the dispersion calculation is initially conducted in the steady state plume mode where downwind distance is the independent variable. Then, if the simulation extends in time beyond the release duration, the remainder of the dispersion calculation is conducted in the transient puff mode where time is the independent variable. For these sources the time-averaged volume concentration is expressed as

$$C(X,Y,Z,T) = CC(X) \cdot [\mathrm{erf}(XA) - \mathrm{erf}(XB)] \cdot [\mathrm{erf}(YA) - \mathrm{erf}(YB)] \cdot \left[\exp\left(-ZA^2\right) + \exp\left(-ZB^2\right)\right] \quad , \tag{56a}$$

where

$$XA = (X - XC + BX) / \left(\sqrt{2} \cdot BETAX\right) \quad ,$$
$$XB = (X - XC - BX) / \left(\sqrt{2} \cdot BETAX\right) \quad ,$$
$$YA = (Y + B) / \left(\sqrt{2} \cdot BETAC\right) \quad ,$$

$$YB = (Y - B) \Big/ \left(\sqrt{2} \cdot BETAC\right) \quad ,$$
$$ZA = (Z - ZC) \Big/ \left(\sqrt{2} \cdot SIG\right) \quad ,$$
$$ZB = (Z + ZC) \Big/ \left(\sqrt{2} \cdot SIG\right) \quad ,$$

and where erf is the error function and exp is the exponential function. The five parameters $CC(X)$, $B(X)$, $BETAC(X)$, $ZC(X)$, and $SIG(X)$ are all functions of downwind distance X and are listed in the output. The three parameters $XC(T)$, $BX(T)$, and $BETAX(T)$ are all functions of time T and are also listed in the output.

When the source is an instantaneous or short duration evaporating pool release, the entire dispersion calculation is conducted in the transient puff mode where time is the independent variable. For this source, the time-averaged volume concentration is expressed as

$$C(X,Y,Z,T) = CC(T) \cdot [\mathrm{erf}(XA) - \mathrm{erf}(XB)] \cdot [\mathrm{erf}(YA) - \mathrm{erf}(YB)] \cdot \left[\exp\left(-ZA^2\right) + \exp\left(-ZB^2\right)\right] \quad , \tag{56b}$$

where

$$XA = (X - XC + BX) \Big/ \left(\sqrt{2} \cdot BETAX\right) \quad ,$$
$$XB = (X - XC - XB) \Big/ \left(\sqrt{2} \cdot BETAX\right) \quad ,$$
$$YA = (Y + B) \Big/ \left(\sqrt{2} \cdot BETAC\right) \quad ,$$
$$YB = (Y - B) \Big/ \left(\sqrt{2} \cdot BETAC\right) \quad ,$$
$$ZA = (Z - ZC) \Big/ \left(\sqrt{2} \cdot SIG\right) \quad ,$$
$$ZB = (Z + ZC) \Big/ \left(\sqrt{2} \cdot SIG\right) \quad ,$$

and where erf is the error function and exp is the exponential function as before. The eight parameters $CC(T)$, $B(T)$, $BETAC(T)$, $ZC(T)$, $SIG(T)$, $XC(T)$, $BX(T)$, and $BETAX(T)$, are all functions of time T and are listed in the output. Equation (56a) or (56b), along with the parameters listed in the output in the Concentration Contour Parameters section, allow the user to calculate the time-averaged volume concentration at any downwind location (X, Y, Z) and time (T) in the calculational domain.

The second output is the Concentration in the $Z = ZP(I)$ Plane. This output gives the time-averaged volume concentration in the horizontal plane at the height $ZP(I)$ above ground. Up to four planes can be selected by the user, all of which are specified in the input. In the output, concentration is listed as a function of downwind distance X. At each downwind distance, the time of maximum concentration, cloud duration, and effective cloud half-width is given. This is followed by the time-averaged volume concentration at six crosswind locations given by

$$Y = N \cdot BBC \quad ,$$

where

$$N = 0.0,\ \ 0.5,\ \ 1.0,\ \ 1.5,\ \ 2.0,\ \ \text{and}\ \ 2.5$$

and BBC is the effective cloud half width. The results for the $ZP(1)$ plane are given first. This is followed by the results for the $ZP(2)$ plane and so on until the results for the last plane are listed.

The final result is the Maximum Centerline Concentration. Here the maximum time-averaged volume concentration along the cloud centerline is given as a function of downwind distance X and the height Z_{pk} at which the maximum ocurs. Generally, $Z_{pk} = 0.0$ except when the source is elevated or the cloud becomes positively buoyant and begins to loft. In the output at each specified downwind location, the code lists the height at which the maximum occurs, the maximum time-averaged volume concentration expressed as a volume fraction from 0.0 to 1.0, the time of maximum concentration, and the cloud duration.

3.4 Concluding Remarks

In conclusion, two cautions are given regarding the use of SLAB predicted values of the time-averaged concentration. The first deals with the comparison of the model predictions with safety standards for a hazardous material and the second deals with the comparison of model predictions with actual field experiments.

Safety standards for hazardous materials are generally given as a maximum average concentration for a specified exposure duration. Often, more than one set of a maximum average concentration level and corresponding exposure duration are given, and it may be necessary to make comparisons using several concentration averaging times. In SLAB, the time-averaged concentration is calculated using the input concentration averaging time TAV. Special care should be taken in interpreting the results when the averaging time TAV is significantly greater than the cloud duration TCD. In this situation, TAV $\gg$ TCD, a significantly reduced time-averaged concentration will be obtained due to the fact that there is no exposure to the cloud during much of the time interval TAV. Consequently, a more meaningful comparison may be obtained if an averaging time on the order of the cloud duration TCD is used.

When models are compared with the experimental results of field tests, it should be recalled that the model concentration results are ensemble averages. Consequently, models attempt to predict the mean value that would be obtained from numerous experiments conducted under the same conditions. Even if a model were 100% accurate, individual observations would be expected to vary about the predicted value; however, the predicted value would be expected to be equal to the mean of all the observations at that downwind location. Thus, the proper evaluation of SLAB, or any atmospheric dispersion model that predicts ensemble averages, requires comparison with numerous experiments over a wide range of spill and meteorological conditions.

4. NUMERICAL EXAMPLES

The following four examples were chosen to demonstrate the different source options and capabilities available in SLAB. The types of sources illustrated are: an evaporating pool release, a two-phase horizontal jet release, an instantaneous vapor release, and a vertical jet vapor release. The first example is a multiple run problem to demonstrate how multiple runs with the same spill conditions, but different meteorological conditions, are setup. The evaporating pool and jet releases are finite duration releases so that the continuous transition from plume mode dispersion to puff mode dispersion can be observed in these examples. The entire input and output files are given for each problem.

4.1 Multiple Run, Evaporating Pool Release

This problem involves two simulations of a liquefied natural gas (LNG) release from an evaporating pool. The first run is a simulation of the Burro 8 experiment conducted by LLNL (Koopman et al., 1982) and the second is a simulation of the same release under neutral atmospheric stability and at a higher ambient wind speed. LNG has a molecular weight that is less than that of air, but is has a boiling point temperature of only 111°K which accounts for the greater density of the cloud compared to the ambient air density. The release is of finite duration with the SLAB dispersion calculation extending beyond the steady state plume region into the transient puff region.

Input File : INPR1

```
    1
    1
0.016043
2238.
111.7
0.
509900.
3348.5
424.1
-1.
0.
111.7
117.
657.
107.
0.
0.
10.
1000.
0.
0.
0.
0.
.0002
2.88
1.92
306.
4.6
0.0
.0665
.0002
2.88
4.00
306.
4.6
0.0
.0000
-1.
```

PROBLEM INPUT

IDSPL	=	1
NCALC	=	1
WMS	=	0.016043
CPS	=	2238.00
TBP	=	111.70
CMEDO	=	0.00
DHE	=	509900.
CPSL	=	3348.50
RHOSL	=	424.10
SPB	=	-1.00
SPC	=	0.00
TS	=	111.70
QS	=	117.00
AS	=	657.00
TSD	=	107.
QTIS	=	0.00
HS	=	0.00
TAV	=	10.00
XFFM	=	1000.00
ZP(1)	=	0.00
ZP(2)	=	0.00
ZP(3)	=	0.00
ZP(4)	=	0.00
Z0	=	0.000200
ZA	=	2.88
UA	=	1.92
TA	=	306.00
RH	=	4.60
STAB	=	0.00
ALA	=	0.0665

RELEASE GAS PROPERTIES

MOLECULAR WEIGHT OF SOURCE GAS (KG)	- WMS	=	1.6043E-02
VAPOR HEAT CAPACITY, CONST. P. (J/KG-K)	- CPS	=	2.2380E+03
TEMPERATURE OF SOURCE GAS (K)	- TS	=	1.1170E+02
DENSITY OF SOURCE GAS (KG/M3)	- RHOS	=	1.7503E+00
BOILING POINT TEMPERATURE	- TBP	=	1.1170E+02
LIQUID MASS FRACTION	- CMEDO	=	0.
LIQUID HEAT CAPACITY (J/KG-K)	- CPSL	=	3.3485E+03
HEAT OF VAPORIZATION (J/KG)	- DHE	=	5.0990E+05
LIQUID SOURCE DENSITY (KG/M3)	- RHOSL	=	4.2410E+02
SATURATION PRESSURE CONSTANT	- SPA	=	6.8083E+00
SATURATION PRESSURE CONSTANT (K)	- SPB	=	9.8389E+02
SATURATION PRESSURE CONSTANT (K)	- SPC	=	0.

SPILL CHARACTERISTICS

SPILL TYPE	- IDSPL	=	1
MASS SOURCE RATE (KG/S)	- QS	=	1.1700E+02
CONTINUOUS SOURCE DURATION (S)	- TSD	=	1.0700E+02
CONTINUOUS SOURCE MASS (KG)	- QTCS	=	1.2519E+04
INSTANTANEOUS SOURCE MASS (KG)	- QTIS	=	0.

SOURCE AREA (M2)	- AS	= 6.5700E+02
VERTICAL VAPOR VELOCITY (M/S)	- WS	= 1.0174E-01
SOURCE HALF WIDTH (M)	- BS	= 1.2816E+01
SOURCE HEIGHT (M)	- HS	= 0.
HORIZONTAL VAPOR VELOCITY (M/S)	- US	= 0.

FIELD PARAMETERS

CONCENTRATION AVERAGING TIME (S)	- TAV	= 1.0000E+01
MIXING LAYER HEIGHT (M)	- HMX	= 7.1244E+02
MAXIMUM DOWNWIND DISTRACE (M)	- XFFM	= 1.0000E+03
CONCENTRATION MEASUREMENT HEIGHT (M)	- ZP(1)	= 0.
	- ZP(2)	= 0.
	- ZP(3)	= 0.
	- ZP(4)	= 0.

AMBIENT METEOROLOGICAL PROPERTIES

MOLECULAR WEIGHT OF AMBIENT AIR (KG)	- WMAE	= 2.8933E-02
HEAT CAPACITY OF AMBIENT AIR AT CONST P. (J/KG-K)	- CPAA	= 1.0071E+03
DENSITY OF AMBIENT AIR (KG/M3)	- RHOA	= 1.1623E+00
AMBIENT MEASUREMENT HEIGHT (M)	- ZA	= 2.8800E+00
AMBIENT ATMOSPHERIC PRESSURE (PA=N/M2=J/M3)	- PA	= 1.0132E+05
AMBIENT WIND SPEED (M/S)	- UA	= 1.9200E+00
AMBIENT TEMPERATURE (K)	- TA	= 3.0600E+02
RELATIVE HUMIDITY (PERCENT)	- RH	= 4.6000E+00
AMBIENT FRICTION VELOCITY (M/S)	- UASTR	= 7.0342E-02
ATMOSPHERIC STABILITY CLASS VALUE	- STAB	= 4.5457E+00
INVERSE MONIN-OBUKHOV LENGTH (1/M)	- ALA	= 6.6500E-02
SURFACE ROUGHNESS HEIGHT (M)	- ZO	= 2.0000E-04

ADDITIONAL PARAMETERS

SUB-STEP MULTIPLIER	- NCALC	= 1
NUMBER OF CALCULATIONAL SUB-STEPS	- NSSM	= 3
ACCELERATION OF GRAVITY (M/S2)	- GRAV	= 9.8066E+00
GAS CONSTANT (J/MOL- K)	- RR	= 8.3143E+00
VON KARMAN CONSTANT	- XK	= 4.1000E-01

1

INSTANTANEOUS SPATIALLY AVERAGED CLOUD PARAMETERS

X	ZC	H	BB	B	BBX	BX	CV	RHO	T	U	UA
-3.11E+01	0.	0.	3.11E+01	2.80E+01	3.11E+01	3.11E+01	0.	1.15E+00	3.06E+02	0.	0.
-2.49E+01	0.	7.65E-01	3.16E+01	2.81E+01	3.30E+01	3.30E+01	3.32E-01	1.27E+00	2.36E+02	8.78E-01	1.23E+00
-1.87E+01	0.	1.20E+00	3.29E+01	2.88E+01	3.49E+01	3.49E+01	4.05E-01	1.30E+00	2.23E+02	8.34E-01	1.36E+00
-1.25E+01	0.	1.60E+00	3.56E+01	3.06E+01	3.68E+01	3.68E+01	4.38E-01	1.31E+00	2.17E+02	7.83E-01	1.44E+00
-6.23E+00	0.	1.88E+00	4.03E+01	3.40E+01	3.87E+01	3.87E+01	4.52E-01	1.31E+00	2.15E+02	7.51E-01	1.49E+00
-4.83E-13	0.	1.89E+00	4.63E+01	3.84E+01	4.06E+01	4.06E+01	4.54E-01	1.31E+00	2.15E+02	8.08E-01	1.49E+00
6.23E+00	0.	1.91E+00	5.29E+01	4.33E+01	4.25E+01	4.25E+01	4.50E-01	1.30E+00	2.16E+02	8.52E-01	1.49E+00
1.25E+01	0.	1.93E+00	5.96E+01	4.82E+01	4.44E+01	4.44E+01	4.43E-01	1.30E+00	2.18E+02	8.95E-01	1.50E+00
1.87E+01	0.	1.97E+00	6.61E+01	5.31E+01	4.63E+01	4.63E+01	4.33E-01	1.29E+00	2.21E+02	9.34E-01	1.50E+00
2.49E+01	0.	2.02E+00	7.24E+01	5.77E+01	4.82E+01	4.81E+01	4.23E-01	1.28E+00	2.23E+02	9.70E-01	1.51E+00
3.11E+01	0.	2.08E+00	7.86E+01	6.22E+01	5.00E+01	5.00E+01	4.13E-01	1.28E+00	2.25E+02	1.00E+00	1.52E+00
3.15E+01	0.	2.07E+00	7.89E+01	6.25E+01	5.03E+01	5.03E+01	4.11E-01	1.28E+00	2.26E+02	1.01E+00	1.52E+00
3.20E+01	0.	2.06E+00	7.93E+01	6.27E+01	5.05E+01	5.05E+01	4.08E-01	1.28E+00	2.26E+02	1.02E+00	1.51E+00
3.24E+01	0.	2.05E+00	7.97E+01	6.31E+01	5.08E+01	5.08E+01	4.06E-01	1.28E+00	2.27E+02	1.02E+00	1.51E+00
3.30E+01	0.	2.04E+00	8.02E+01	6.34E+01	5.11E+01	5.11E+01	4.03E-01	1.27E+00	2.27E+02	1.03E+00	1.51E+00
3.36E+01	0.	2.03E+00	8.08E+01	6.39E+01	5.15E+01	5.15E+01	4.00E-01	1.27E+00	2.28E+02	1.04E+00	1.51E+00
3.42E+01	0.	2.02E+00	8.14E+01	6.43E+01	5.19E+01	5.19E+01	3.97E-01	1.27E+00	2.29E+02	1.05E+00	1.51E+00
3.50E+01	0.	2.01E+00	8.21E+01	6.48E+01	5.24E+01	5.24E+01	3.94E-01	1.27E+00	2.29E+02	1.06E+00	1.51E+00
3.59E+01	0.	1.99E+00	8.29E+01	6.54E+01	5.29E+01	5.29E+01	3.90E-01	1.27E+00	2.30E+02	1.07E+00	1.50E+00
3.68E+01	0.	1.98E+00	8.37E+01	6.60E+01	5.35E+01	5.35E+01	3.87E-01	1.27E+00	2.31E+02	1.08E+00	1.50E+00
3.79E+01	0.	1.97E+00	8.47E+01	6.67E+01	5.41E+01	5.41E+01	3.83E-01	1.26E+00	2.32E+02	1.09E+00	1.50E+00
3.91E+01	0.	1.95E+00	8.57E+01	6.75E+01	5.48E+01	5.48E+01	3.79E-01	1.26E+00	2.33E+02	1.10E+00	1.50E+00
4.04E+01	0.	1.93E+00	8.69E+01	6.84E+01	5.57E+01	5.57E+01	3.75E-01	1.26E+00	2.33E+02	1.11E+00	1.50E+00
4.19E+01	0.	1.92E+00	8.82E+01	6.93E+01	5.66E+01	5.66E+01	3.71E-01	1.26E+00	2.34E+02	1.12E+00	1.49E+00
4.36E+01	0.	1.90E+00	8.97E+01	7.04E+01	5.76E+01	5.76E+01	3.66E-01	1.26E+00	2.35E+02	1.13E+00	1.49E+00
4.55E+01	0.	1.89E+00	9.13E+01	7.16E+01	5.88E+01	5.87E+01	3.60E-01	1.25E+00	2.37E+02	1.14E+00	1.49E+00
4.76E+01	0.	1.87E+00	9.31E+01	7.29E+01	6.00E+01	6.00E+01	3.54E-01	1.25E+00	2.38E+02	1.15E+00	1.49E+00
5.00E+01	0.	1.86E+00	9.51E+01	7.44E+01	6.15E+01	6.15E+01	3.47E-01	1.25E+00	2.39E+02	1.17E+00	1.48E+00
5.27E+01	0.	1.84E+00	9.73E+01	7.60E+01	6.31E+01	6.31E+01	3.40E-01	1.24E+00	2.41E+02	1.18E+00	1.48E+00
5.57E+01	0.	1.76E+00	9.97E+01	7.78E+01	6.72E+01	6.66E+01	3.29E-01	1.24E+00	2.43E+02	1.19E+00	1.47E+00
5.91E+01	0.	1.69E+00	1.02E+02	7.98E+01	7.17E+01	7.04E+01	3.16E-01	1.24E+00	2.45E+02	1.19E+00	1.46E+00
6.29E+01	0.	1.63E+00	1.05E+02	8.19E+01	7.66E+01	7.45E+01	3.01E-01	1.23E+00	2.48E+02	1.20E+00	1.45E+00
6.73E+01	0.	1.59E+00	1.08E+02	8.42E+01	8.19E+01	7.88E+01	2.85E-01	1.23E+00	2.51E+02	1.22E+00	1.44E+00
7.22E+01	0.	1.55E+00	1.12E+02	8.67E+01	8.76E+01	8.33E+01	2.68E-01	1.22E+00	2.54E+02	1.23E+00	1.43E+00
7.78E+01	0.	1.53E+00	1.15E+02	8.93E+01	9.36E+01	8.80E+01	2.49E-01	1.22E+00	2.58E+02	1.25E+00	1.43E+00
8.42E+01	0.	1.54E+00	1.19E+02	9.20E+01	1.00E+02	9.29E+01	2.29E-01	1.21E+00	2.62E+02	1.27E+00	1.43E+00
9.15E+01	0.	1.56E+00	1.23E+02	9.48E+01	1.07E+02	9.78E+01	2.09E-01	1.20E+00	2.66E+02	1.30E+00	1.43E+00
9.99E+01	0.	1.60E+00	1.27E+02	9.77E+01	1.14E+02	1.03E+02	1.87E-01	1.19E+00	2.70E+02	1.32E+00	1.44E+00
1.09E+02	0.	1.67E+00	1.31E+02	1.01E+02	1.21E+02	1.08E+02	1.66E-01	1.19E+00	2.75E+02	1.35E+00	1.45E+00
1.20E+02	0.	1.77E+00	1.35E+02	1.04E+02	1.28E+02	1.12E+02	1.46E-01	1.18E+00	2.79E+02	1.38E+00	1.47E+00
1.33E+02	0.	1.89E+00	1.39E+02	1.07E+02	1.36E+02	1.17E+02	1.27E-01	1.18E+00	2.83E+02	1.42E+00	1.49E+00
1.47E+02	0.	2.04E+00	1.44E+02	1.10E+02	1.43E+02	1.22E+02	1.09E-01	1.17E+00	2.86E+02	1.45E+00	1.51E+00
1.64E+02	0.	2.23E+00	1.48E+02	1.13E+02	1.51E+02	1.26E+02	9.28E-02	1.17E+00	2.89E+02	1.49E+00	1.54E+00
1.83E+02	0.	2.46E+00	1.52E+02	1.15E+02	1.60E+02	1.30E+02	7.82E-02	1.16E+00	2.92E+02	1.52E+00	1.57E+00
2.05E+02	0.	2.74E+00	1.56E+02	1.18E+02	1.68E+02	1.34E+02	6.55E-02	1.16E+00	2.95E+02	1.56E+00	1.60E+00
2.30E+02	0.	3.06E+00	1.61E+02	1.21E+02	1.77E+02	1.37E+02	5.45E-02	1.16E+00	2.97E+02	1.60E+00	1.63E+00
2.60E+02	0.	3.44E+00	1.65E+02	1.24E+02	1.87E+02	1.41E+02	4.50E-02	1.16E+00	2.98E+02	1.65E+00	1.67E+00
2.93E+02	0.	3.89E+00	1.69E+02	1.27E+02	1.97E+02	1.44E+02	3.70E-02	1.16E+00	3.00E+02	1.69E+00	1.71E+00
3.32E+02	0.	4.40E+00	1.74E+02	1.29E+02	2.08E+02	1.47E+02	3.03E-02	1.16E+00	3.01E+02	1.73E+00	1.76E+00
3.76E+02	0.	5.00E+00	1.78E+02	1.32E+02	2.20E+02	1.50E+02	2.47E-02	1.15E+00	3.02E+02	1.78E+00	1.79E+00
4.27E+02	0.	5.68E+00	1.83E+02	1.34E+02	2.33E+02	1.53E+02	2.01E-02	1.15E+00	3.03E+02	1.82E+00	1.83E+00
4.85E+02	0.	6.46E+00	1.87E+02	1.37E+02	2.47E+02	1.55E+02	1.63E-02	1.15E+00	3.03E+02	1.86E+00	1.87E+00
5.53E+02	0.	7.35E+00	1.92E+02	1.40E+02	2.62E+02	1.57E+02	1.31E-02	1.15E+00	3.04E+02	1.91E+00	1.92E+00
6.30E+02	0.	8.36E+00	1.97E+02	1.42E+02	2.79E+02	1.59E+02	1.06E-02	1.15E+00	3.04E+02	1.96E+00	1.96E+00

7.19E+02	0.	9.50E+00	2.02E+02	1.45E+02	2.98E+02	1.61E+02	8.50E-03	1.15E+00	3.05E+02	2.00E+00	2.01E+00
8.21E+02	0.	1.08E+01	2.08E+02	1.47E+02	3.20E+02	1.63E+02	6.82E-03	1.15E+00	3.05E+02	2.06E+00	2.05E+00
9.38E+02	0.	1.22E+01	2.13E+02	1.49E+02	3.43E+02	1.65E+02	5.46E-03	1.15E+00	3.05E+02	2.09E+00	2.10E+00
1.07E+03	0.	1.39E+01	2.19E+02	1.52E+02	3.69E+02	1.66E+02	4.36E-03	1.15E+00	3.05E+02	2.14E+00	2.14E+00
1.23E+03	0.	1.57E+01	2.25E+02	1.54E+02	3.99E+02	1.67E+02	3.48E-03	1.15E+00	3.05E+02	2.18E+00	2.19E+00
1.40E+03	0.	1.77E+01	2.32E+02	1.56E+02	4.32E+02	1.68E+02	2.77E-03	1.15E+00	3.06E+02	2.23E+00	2.23E+00
1.60E+03	0.	1.99E+01	2.39E+02	1.59E+02	4.69E+02	1.69E+02	2.20E-03	1.15E+00	3.06E+02	2.27E+00	2.27E+00

1

X	CM	CMV	CMDA	CMW	CMWV	WC	VG	UG	W	V	VX
-3.11E+01	0.	0.	9.98E-01	1.52E-03	1.52E-03	0.	0.	0.	4.04E-01	4.31E-02	0.
-2.49E+01	2.16E-01	2.16E-01	7.83E-01	1.19E-03	1.87E-04	0.	5.06E-02	0.	2.57E-02	3.62E-02	1.26E-01
-1.87E+01	2.74E-01	2.74E-01	7.25E-01	1.10E-03	4.84E-05	0.	1.77E-01	0.	2.14E-02	4.81E-02	1.36E-01
-1.25E+01	3.02E-01	3.02E-01	6.97E-01	1.06E-03	2.57E-05	0.	3.65E-01	0.	2.00E-02	5.72E-02	1.43E-01
-6.23E+00	3.13E-01	3.13E-01	6.86E-01	1.04E-03	2.04E-05	0.	5.85E-01	0.	1.98E-02	6.28E-02	1.48E-01
-4.83E-13	3.16E-01	3.16E-01	6.83E-01	1.04E-03	2.05E-05	0.	7.39E-01	0.	2.01E-02	5.88E-02	1.48E-01
6.23E+00	3.12E-01	3.12E-01	6.87E-01	1.04E-03	2.38E-05	0.	8.26E-01	0.	2.04E-02	5.68E-02	1.49E-01
1.25E+01	3.06E-01	3.06E-01	6.93E-01	1.05E-03	2.97E-05	0.	8.70E-01	0.	2.06E-02	5.30E-02	1.49E-01
1.87E+01	2.98E-01	2.98E-01	7.01E-01	1.06E-03	3.82E-05	0.	8.87E-01	0.	2.07E-02	5.07E-02	1.50E-01
2.49E+01	2.89E-01	2.89E-01	7.10E-01	1.08E-03	4.94E-05	0.	8.89E-01	0.	2.07E-02	4.87E-02	1.50E-01
3.11E+01	2.80E-01	2.80E-01	7.18E-01	1.09E-03	6.33E-05	0.	8.85E-01	0.	2.07E-02	4.71E-02	1.51E-01
3.15E+01	2.79E-01	2.79E-01	7.20E-01	1.09E-03	6.67E-05	0.	8.85E-01	0.	2.06E-02	4.66E-02	1.51E-01
3.20E+01	2.77E-01	2.77E-01	7.22E-01	1.10E-03	7.03E-05	0.	8.86E-01	0.	2.03E-02	4.60E-02	1.51E-01
3.24E+01	2.75E-01	2.75E-01	7.24E-01	1.10E-03	7.45E-05	0.	8.87E-01	0.	1.98E-02	4.54E-02	1.51E-01
3.30E+01	2.72E-01	2.72E-01	7.27E-01	1.10E-03	7.92E-05	0.	8.89E-01	0.	1.92E-02	4.48E-02	1.51E-01
3.36E+01	2.70E-01	2.70E-01	7.29E-01	1.11E-03	8.45E-05	0.	8.90E-01	0.	1.83E-02	4.41E-02	1.51E-01
3.42E+01	2.67E-01	2.67E-01	7.32E-01	1.11E-03	9.06E-05	0.	8.91E-01	0.	1.73E-02	4.34E-02	1.50E-01
3.50E+01	2.65E-01	2.65E-01	7.34E-01	1.11E-03	9.73E-05	0.	8.93E-01	0.	1.63E-02	4.27E-02	1.50E-01
3.59E+01	2.62E-01	2.62E-01	7.37E-01	1.12E-03	1.06E-04	0.	8.95E-01	0.	1.52E-02	4.20E-02	1.50E-01
3.68E+01	2.59E-01	2.59E-01	7.40E-01	1.12E-03	1.13E-04	0.	8.98E-01	0.	1.43E-02	4.12E-02	1.50E-01
3.79E+01	2.56E-01	2.56E-01	7.43E-01	1.13E-03	1.22E-04	0.	9.01E-01	0.	1.34E-02	4.04E-02	1.50E-01
3.91E+01	2.53E-01	2.53E-01	7.46E-01	1.13E-03	1.33E-04	0.	9.04E-01	0.	1.28E-02	3.96E-02	1.49E-01
4.04E+01	2.50E-01	2.50E-01	7.49E-01	1.14E-03	1.45E-04	0.	9.07E-01	0.	1.23E-02	3.87E-02	1.49E-01
4.19E+01	2.46E-01	2.46E-01	7.53E-01	1.14E-03	1.59E-04	0.	9.09E-01	0.	1.20E-02	3.78E-02	1.49E-01
4.36E+01	2.42E-01	2.42E-01	7.57E-01	1.15E-03	1.76E-04	0.	9.11E-01	0.	1.20E-02	3.69E-02	1.49E-01
4.55E+01	2.38E-01	2.38E-01	7.61E-01	1.15E-03	1.97E-04	0.	9.12E-01	0.	1.20E-02	3.60E-02	1.48E-01
4.76E+01	2.33E-01	2.33E-01	7.66E-01	1.16E-03	2.22E-04	0.	9.12E-01	0.	1.22E-02	3.50E-02	1.48E-01
5.00E+01	2.28E-01	2.28E-01	7.71E-01	1.17E-03	2.54E-04	0.	9.10E-01	0.	1.23E-02	3.40E-02	1.48E-01
5.27E+01	2.22E-01	2.22E-01	7.77E-01	1.18E-03	2.93E-04	0.	9.06E-01	1.40E+00	1.25E-02	3.29E-02	1.48E-01
5.57E+01	2.13E-01	2.13E-01	7.85E-01	1.19E-03	3.60E-04	0.	8.90E-01	1.37E+00	1.30E-02	3.16E-02	1.46E-01
5.91E+01	2.04E-01	2.04E-01	7.95E-01	1.21E-03	4.50E-04	0.	8.68E-01	1.33E+00	1.34E-02	3.02E-02	1.43E-01
6.29E+01	1.93E-01	1.93E-01	8.06E-01	1.22E-03	5.73E-04	0.	8.39E-01	1.27E+00	1.38E-02	2.89E-02	1.42E-01
6.73E+01	1.81E-01	1.81E-01	8.17E-01	1.24E-03	7.43E-04	0.	8.06E-01	1.21E+00	1.41E-02	2.75E-02	1.41E-01
7,22E+01	1.69E-01	1.69E-01	8.30E-01	1.26E-03	9.71E-04	0.	7.64E-01	1.14E+00	1.43E-02	2.62E-02	1.41E-01
7.78E+01	1.55E-01	1.55E-01	8.43E-01	1.28E-03	1.27E-03	0.	7.20E-01	1.06E+00	1.44E-02	2.49E-02	1.40E-01
8.42E+01	1.42E-01	1.42E-01	8.57E-01	1.30E-03	1.30E-03	0.	6.71E-01	9.80E-01	1.47E-02	2.38E-02	1.40E-01
9.15E+01	1.27E-01	1.27E-01	8.71E-01	1.32E-03	1.32E-03	0.	6.19E-01	8.92E-01	1.50E-02	2.28E-02	1.41E-01
9.99E+01	1.13E-01	1.13E-01	8.85E-01	1.34E-03	1.34E-03	0.	5.65E-01	8.04E-01	1.52E-02	2.20E-02	1.41E-01
1.09E+02	9.97E-02	9.97E-02	8.99E-01	1.36E-03	1.36E-03	0.	5.11E-01	7.17E-01	1.54E-02	2.13E-02	1.42E-01
1.20E+02	8.67E-02	8.67E-02	9.12E-01	1.38E-03	1.38E-03	0.	4.59E-01	6.34E-01	1.57E-02	2.08E-02	1.44E-01
1.33E+02	7.46E-02	7.46E-02	9.24E-01	1.40E-03	1.40E-03	0.	4.09E-01	5.56E-01	1.59E-02	2.04E-02	1.46E-01
1.47E+02	6.35E-02	6.35E-02	9.35E-01	1.42E-03	1.42E-03	0.	3.62E-01	4.85E-01	1.61E-02	2.02E-02	1.48E-01
1.64E+02	5.36E-02	5.36E-02	9.45E-01	1.43E-03	1.43E-03	0.	3.20E-01	4.21E-01	1.63E-02	2.01E-02	1.51E-01
1.83E+02	4.50E-02	4.50E-02	9.54E-01	1.45E-03	1.45E-03	0.	2.82E-01	3.64E-01	1.66E-02	2.01E-02	1.54E-01
2.05E+02	3.74E-02	3.74E-02	9.61E-01	1.46E-03	1.46E-03	0.	2.48E-01	3.14E-01	1.68E-02	2.01E-02	1.58E-01
2.30E+02	3.10E-02	3.10E-02	9.68E-01	1.47E-03	1.47E-03	0.	2.18E-01	2.71E-01	1.71E-02	2.03E-02	1.62E-01
2.60E+02	2.55E-02	2.55E-02	9.73E-01	1.48E-03	1.48E-03	0.	1.92E-01	2.33E-01	1.73E-02	2.04E-02	1.66E-01
2.93E+02	2.09E-02	2.09E-02	9.78E-01	1.48E-03	1.48E-03	0.	1.69E-01	2.01E-01	1.76E-02	2.06E-02	1.70E-01
3.32E+02	1.70E-02	1.70E-02	9.81E-01	1.49E-03	1.49E-03	0.	1.49E-01	1.73E-01	1.77E-02	2.08E-02	1.75E-01
3.76E+02	1.39E-02	1.39E-02	9.85E-01	1.49E-03	1.49E-03	0.	1.32E-01	1.49E-01	1.78E-02	2.10E-02	1.80E-01
4.27E+02	1.12E-02	1.12E-02	9.87E-01	1.50E-03	1.50E-03	0.	1.17E-01	1.29E-01	1.79E-02	2.12E-02	1.84E-01
4.85E+02	9.09E-03	9.09E-03	9.89E-01	1.50E-03	1.50E-03	0.	1.04E-01	1.11E-01	1.80E-02	2.15E-02	1.89E-01
5.53E+02	7.33E-03	7.33E-03	9.91E-01	1.50E-03	1.50E-03	0.	9.22E-02	9.60E-02	1.81E-02	2.17E-02	1.94E-01
6.30E+02	5.90E-03	5.90E-03	9.93E-01	1.51E-03	1.51E-03	0.	8.19E-02	8.27E-02	1.81E-02	2.19E-02	1.98E-01
7.19E+02	4.73E-03	4.73E-03	9.94E-01	1.51E-03	1.51E-03	0.	7.28E-02	7.12E-02	1.80E-02	2.21E-02	2.03E-01
8.21E+02	3.79E-03	3.79E-03	9.95E-01	1.51E-03	1.51E-03	0.	6.46E-02	6.12E-02	1.79E-02	2.23E-02	2.07E-01
9.38E+02	3.03E-03	3.03E-03	9.95E-01	1.51E-03	1.51E-03	0.	5.71E-02	5.24E-02	1.77E-02	2.26E-02	2.11E-01

1.07E+03	2.42E-03	2.42E-03	9.96E-01	1.51E-03	1.51E-03	0.	5.04E-02	4.47E-02	1.75E-02	2.26E-02	2.14E-01
1.23E+03	1.93E-03	1.93E-03	9.97E-01	1.51E-03	1.51E-03	0.	4.43E-02	3.80E-02	1.73E-02	2.27E-02	2.17E-01
1.40E+03	1.54E-03	1.54E-03	9.97E-01	1.51E-03	1.51E-03	0.	3.87E-02	3.21E-02	1.70E-02	2.29E-02	2.20E-01
1.60E+03	1.22E-03	1.22E-03	9.97E-01	1.51E-03	1.51E-03	0.	3.35E-02	2.70E-02	1.66E-02	2.29E-02	2.23E-01

1

TIME AVERAGED (TAV =   10. S) VOLUME CONCENTRATION: CONCENTRATION CONTOUR PARAMETERS

C(X,Y,Z,T) = CC(X) * (ERF(XA)-ERF(XB)) * (ERF(YA)-ERF(YB)) * (EXP(-ZA*ZA)+EXP(-ZB*ZB))

```
C(X,Y,Z,T) = CONCENTRATION (VOLUME FRACTION) AT (X,Y,Z,T)
         X = DOWNWIND DISTANCE (M)
         Y = CROSSWIND HORIZONTAL DISTANCE (M)
         Z = HEIGHT (M)
         T = TIME (S)

       ERF = ERROR FUNCTON
        XA = (X-XC+BX)/(SR2*BETAX)
        XB = (X-XC-BX)/(SR2*BETAX)
        YA = (Y+B)/(SR2*BETAC)
        YB = (Y-B)/(SR2*BETAC)
       EXP = EXPONENTIAL FUNCTION
        ZA = (Z-ZC)/(SR2*SIG)
        ZB = (Z+ZC)/(SR2*SIG)
       SR2 = SQRT(2.0)
```

X	CC(X)	B(X)	BETAC(X)	ZC(X)	SIG(X)	T	XC(T)	BX(T)	BETAX(T)
-3.11E+01	0.	2.80E+01	7.84E+00	0.	0.	1.97E+01	0.	3.11E+01	2.54E-01
-2.49E+01	6.45E-02	2.81E+01	8.32E+00	0.	4.42E-01	2.38E+01	3.11E+00	3.30E+01	2.70E-01
-1.87E+01	7.98E-02	2.88E+01	9.12E+00	0.	6.92E-01	2.80E+01	6.23E+00	3.49E+01	2.85E-01
-1.25E+01	8.79E-02	3.06E+01	1.04E+01	0.	9.21E-01	3.26E+01	9.34E+00	3.68E+01	3.01E-01
-6.23E+00	9.25E-02	3.40E+01	1.25E+01	0.	1.09E+00	3.72E+01	1.25E+01	3.87E+01	3.16E-01
-4.83E-13	9.46E-02	3.84E+01	1.49E+01	0.	1.09E+00	4.23E+01	1.56E+01	4.06E+01	3.31E-01
6.23E+00	9.51E-02	4.33E+01	1.75E+01	0.	1.10E+00	4.74E+01	1.87E+01	4.25E+01	3.47E-01
1.25E+01	9.45E-02	4.82E+01	2.02E+01	0.	1.12E+00	5.30E+01	2.18E+01	4.44E+01	3.62E-01
1.87E+01	9.33E-02	5.31E+01	2.27E+01	0.	1.14E+00	5.85E+01	2.49E+01	4.63E+01	3.78E-01
2.49E+01	9.17E-02	5.77E+01	2.52E+01	0.	1.17E+00	6.45E+01	2.80E+01	4.81E+01	3.93E-01
3.11E+01	9.00E-02	6.22E+01	2.77E+01	0.	1.20E+00	7.05E+01	3.11E+01	5.00E+01	4.09E-01
3.15E+01	8.96E-02	6.25E+01	2.78E+01	0.	1.19E+00	7.13E+01	3.16E+01	5.03E+01	4.10E-01
3.20E+01	8.91E-02	6.27E+01	2.80E+01	0.	1.19E+00	7.21E+01	3.20E+01	5.05E+01	4.13E-01
3.24E+01	8.86E-02	6.31E+01	2.81E+01	0.	1.18E+00	7.31E+01	3.24E+01	5.08E+01	4.15E-01
3.30E+01	8.80E-02	6.34E+01	2.83E+01	0.	1.18E+00	7.41E+01	3.30E+01	5.11E+01	4.18E-01
3.36E+01	8.74E-02	6.39E+01	2.86E+01	0.	1.17E+00	7.63E+01	3.36E+01	5.15E+01	4.21E-01
3.42E+01	8.68E-02	6.43E+01	2.88E+01	0.	1.16E+00	7.66E+01	3.42E+01	5.19E+01	4.24E-01
3.50E+01	8.61E-02	6.48E+01	2.91E+01	0.	1.16E+00	7.80E+01	3.50E+01	5.24E+01	4.28E-01
3.59E+01	8.55E-02	6.54E+01	2.94E+01	0.	1.15E+00	7.96E+01	3.59E+01	5.29E+01	4.32E-01
3.68E+01	8.47E-02	6.60E+01	2.97E+01	0.	1.14E+00	8.14E+01	3.68E+01	5.35E+01	4.37E-01
3.79E+01	8.40E-02	6.67E+01	3.01E+01	0.	1.13E+00	8.34E+01	3.79E+01	5.41E+01	4.42E-01
3.91E+01	8.32E-02	6.75E+01	3.05E+01	0.	1.13E+00	8.56E+01	3.91E+01	5.48E+01	4.48E-01
4.04E+01	8.24E-02	6.84E+01	3.10E+01	0.	1.12E+00	8.80E+01	4.04E+01	5.57E+01	4.54E-01
4.19E+01	8.15E-02	6.93E+01	3.15E+01	0.	1.11E+00	9.07E+01	4.19E+01	5.66E+01	4.62E-01
4.36E+01	8.05E-02	7.04E+01	3.21E+01	0.	1.10E+00	9.37E+01	4.36E+01	5.76E+01	4.70E-01
4.55E+01	7.93E-02	7.16E+01	3.27E+01	0.	1.09E+00	9.71E+01	4.55E+01	5.87E+01	4.80E-01
4.76E+01	7.81E-02	7.29E+01	3.34E+01	0.	1.08E+00	1.01E+02	4.76E+01	6.00E+01	4.90E-01
5.00E+01	7.67E-02	7.44E+01	3.42E+01	0.	1.07E+00	1.05E+02	5.00E+01	6.15E+01	5.02E-01
5.27E+01	7.51E-02	7.60E+01	3.51E+01	0.	1.07E+00	1.09E+02	5.27E+01	6.31E+01	5.15E-01
5.57E+01	7.34E-02	7.78E+01	3.60E+01	0.	1.02E+00	1.10E+02	5.57E+01	6.66E+01	5.25E+00
5.91E+01	7.13E-02	7.98E+01	3.70E+01	0.	9.77E-01	1.12E+02	5.91E+01	7.04E+01	7.95E+00
6.29E+01	6.89E-02	8.19E+01	3.82E+01	0.	9.43E-01	1.16E+02	6.29E+01	7.45E+01	1.05E+01
6.73E+01	6.60E-02	8.42E+01	3.94E+01	0.	9.15E-01	1.19E+02	6.73E+01	7.88E+01	1.30E+01
7.22E+01	6.27E-02	8.67E+01	4.07E+01	0.	8.97E-01	1.23E+02	7.22E+01	8.33E+01	1.56E+01
7.78E+01	5.91E-02	8.93E+01	4.21E+01	0.	8.86E-01	1.28E+02	7.78E+01	8.80E+01	1.84E+01
8.42E+01	5.51E-02	9.20E+01	4.36E+01	0.	8.87E-01	1.33E+02	8.42E+01	9.29E+01	2.14E+01
9.15E+01	5.09E-02	9.48E+01	4.51E+01	0.	9.00E-01	1.38E+02	9.15E+01	9.78E+01	2.45E+01

9.99E+01	4.65E-02	9.77E+01	4.67E+01	0.	9.26E-01	1.45E+02	9.99E+01	1.03E+02	2.79E+01
1.09E+02	4.20E-02	1.01E+02	4.84E+01	0.	9.65E-01	1.52E+02	1.09E+02	1.08E+02	3.15E+01
1.20E+02	3.75E-02	1.04E+02	5.01E+01	0.	1.02E+00	1.60E+02	1.20E+02	1.12E+02	3.54E+01
1.33E+02	3.32E-02	1.07E+02	5.18E+01	0.	1.09E+00	1.69E+02	1.33E+02	1.17E+02	3.95E+01
1.47E+02	2.91E-02	1.10E+02	5.36E+01	0.	1.18E+00	1.79E+02	1.47E+02	1.22E+02	4.38E+01
1.64E+02	2.53E-02	1.13E+02	5.53E+01	0.	1.29E+00	1.90E+02	1.64E+02	1.26E+02	4.85E+01
1.83E+02	2.19E-02	1.15E+02	5.72E+01	0.	1.42E+00	2.03E+02	1.83E+02	1.30E+02	5.35E+01
2.05E+02	1.88E-02	1.18E+02	5.90E+01	0.	1.58E+00	2.17E+02	2.06E+02	1.34E+02	5.89E+01
2.30E+02	1.61E-02	1.21E+02	6.09E+01	0.	1.77E+00	2.33E+02	2.30E+02	1.37E+02	6.46E+01
2.60E+02	1.37E-02	1.24E+02	6.29E+01	0.	1.99E+00	2.51E+02	2.60E+02	1.41E+02	7.08E+01
2.93E+02	1.17E-02	1.27E+02	6.49E+01	0.	2.24E+00	2.71E+02	2.93E+02	1.44E+02	7.75E+01
3.32E+02	9.94E-03	1.29E+02	6.69E+01	0.	2.54E+00	2.94E+02	3.32E+02	1.47E+02	8.48E+01
3.76E+02	8.45E-03	1.32E+02	6.91E+01	0.	2.89E+00	3.19E+02	3.76E+02	1.50E+02	9.27E+01
4.27E+02	7.18E-03	1.34E+02	7.13E+01	0.	3.28E+00	3.47E+02	4.27E+02	1.53E+02	1.01E+02
4.85E+02	6.11E-03	1.37E+02	7.37E+01	0.	3.73E+00	3.79E+02	4.86E+02	1.55E+02	1.11E+02
5.53E+02	5.21E-03	1.40E+02	7.62E+01	0.	4.24E+00	4.15E+02	5.53E+02	1.57E+02	1.21E+02
6.30E+02	4.44E-03	1.42E+02	7.89E+01	0.	4.83E+00	4.55E+02	6.30E+02	1.59E+02	1.32E+02
7.19E+02	3.80E-03	1.46E+02	8.17E+01	0.	5.49E+00	5.00E+02	7.19E+02	1.61E+02	1.45E+02
8.21E+02	3.26E-03	1.47E+02	8.47E+01	0.	6.23E+00	5.50E+02	8.21E+02	1.63E+02	1.59E+02
9.38E+02	2.80E-03	1.49E+02	8.78E+01	0.	7.06E+00	6.07E+02	9.38E+02	1.65E+02	1.74E+02
1.07E+03	2.42E-03	1.52E+02	9.12E+01	0.	8.00E+00	6.70E+02	1.07E+03	1.66E+02	1.91E+02
1.23E+03	2.09E-03	1.54E+02	9.49E+01	0.	9.04E+00	7.41E+02	1.23E+03	1.67E+02	2.09E+02
1.40E+03	1.82E-03	1.56E+02	9.87E+01	0.	1.02E+01	8.21E+02	1.40E+03	1.68E+02	2.30E+02
1.60E+03	1.58E-03	1.59E+02	1.03E+02	0.	1.15E+01	9.10E+02	1.60E+03	1.69E+02	2.52E+02

1

TIME AVERAGED (TAV = 10. S) VOLUME CONCENTRATION: CONCENTRATION IN THE Z = 0.00 PLANE.

DOWNWIND DISTANCE X (M)	TIME OF MAX CONC (S)	CLOUD DURATION (S)	EFFECTIVE HALF WIDTH BBC (M)	AVERAGE CONCENTRATION (VOLUME FRACTION) AT (X,Y,Z) Y/BBC= 0.0	Y/BBC= 0.5	Y/BBC= 1.0	Y/BBC= 1.5	Y/BBC= 2.0	Y/BBC= 2.5
-3.11E+01	8.51E+01	1.07E+02	3.11E+01	0.	0.	0.	0.	0.	0.
-2.49E+01	7.88E+01	1.07E+02	3.16E+01	5.15E-01	4.80E-01	1.74E-01	5.27E-03	6.31E-06	2.40E-10
-1.87E+01	7.25E+01	1.07E+02	3.29E+01	6.37E-01	5.83E-01	2.10E-01	7.88E-03	1.64E-05	1.65E-09
-1.25E+01	6.61E+01	1.07E+02	3.56E+01	7.01E-01	6.26E-01	2.24E-01	1.04E-02	3.66E-05	8.23E-09
-6.23E+00	5.98E+01	1.07E+02	4.03E+01	7.35E-01	6.41E-01	2.27E-01	1.26E-02	7.04E-05	3.34E-08
-4.83E-13	5.35E+01	1.07E+02	4.63E+01	7.49E-01	6.41E-01	2.26E-01	1.42E-02	1.07E-04	8.36E-08
6.23E+00	5.98E+01	1.07E+02	5.29E+01	7.50E-01	6.32E-01	2.22E-01	1.52E-02	1.40E-04	1.61E-07
1.25E+01	6.61E+01	1.07E+02	5.96E+01	7.43E-01	6.20E-01	2.17E-01	1.57E-02	1.67E-04	2.27E-07
1.87E+01	7.25E+01	1.07E+02	6.61E+01	7.31E-01	6.05E-01	2.11E-01	1.60E-02	1.88E-04	3.04E-07
2.49E+01	7.88E+01	1.07E+02	7.24E+01	7.17E-01	5.89E-01	2.06E-01	1.61E-02	2.05E-04	3.80E-07
3.11E+01	8.51E+01	1.07E+02	7.85E+01	7.02E-01	5.74E-01	2.00E-01	1.60E-02	2.19E-04	4.52E-07
3.15E+01	8.55E+01	1.07E+02	7.89E+01	6.99E-01	5.70E-01	1.99E-01	1.60E-02	2.19E-04	4.54E-07
3.20E+01	8.59E+01	1.07E+02	7.93E+01	6.95E-01	5.67E-01	1.98E-01	1.59E-02	2.19E-04	4.57E-07
3.24E+01	8.64E+01	1.07E+02	7.97E+01	6.91E-01	5.63E-01	1.96E-01	1.58E-02	2.19E-04	4.60E-07
3.30E+01	8.70E+01	1.07E+02	8.02E+01	6.86E-01	5.60E-01	1.95E-01	1.58E-02	2.19E-04	4.63E-07
3.36E+01	8.76E+01	1.07E+02	8.08E+01	6.82E-01	5.55E-01	1.94E-01	1.57E-02	2.19E-04	4.67E-07
3.42E+01	8.83E+01	1.07E+02	8.14E+01	6.77E-01	5.51E-01	1.92E-01	1.56E-02	2.19E-04	4.71E-07
3.50E+01	8.90E+01	1.07E+02	8.21E+01	6.71E-01	5.46E-01	1.90E-01	1.55E-02	2.19E-04	4.76E-07
3.59E+01	8.99E+01	1.07E+02	8.29E+01	6.66E-01	5.42E-01	1.89E-01	1.54E-02	2.19E-04	4.81E-07
3.68E+01	9.09E+01	1.07E+02	8.37E+01	6.60E-01	5.37E-01	1.87E-01	1.53E-02	2.19E-04	4.86E-07
3.79E+01	9.19E+01	1.07E+02	8.47E+01	6.54E-01	5.31E-01	1.86E-01	1.52E-02	2.19E-04	4.93E-07
3.91E+01	9.32E+01	1.07E+02	8.57E+01	6.48E-01	5.26E-01	1.83E-01	1.51E-02	2.19E-04	4.99E-07
4.04E+01	9.45E+01	1.07E+02	8.69E+01	6.41E-01	5.20E-01	1.81E-01	1.49E-02	2.19E-04	5.07E-07
4.19E+01	9.61E+01	1.07E+02	8.82E+01	6.33E-01	5.14E-01	1.79E-01	1.48E-02	2.19E-04	5.14E-07
4.36E+01	9.78E+01	1.07E+02	8.97E+01	6.25E-01	5.07E-01	1.76E-01	1.47E-02	2.19E-04	5.22E-07
4.55E+01	9.97E+01	1.07E+02	9.13E+01	6.16E-01	4.99E-01	1.74E-01	1.45E-02	2.19E-04	5.30E-07
4.76E+01	1.02E+02	1.07E+02	9.31E+01	6.07E-01	4.90E-01	1.71E-01	1.43E-02	2.18E-04	5.38E-07
5.00E+01	1.04E+02	1.07E+02	9.51E+01	5.95E-01	4.81E-01	1.67E-01	1.41E-02	2.17E-04	5.46E-07
5.27E+01	1.07E+02	1.07E+02	9.73E+01	5.83E-01	4.70E-01	1.63E-01	1.39E-02	2.16E-04	5.53E-07
5.57E+01	1.10E+02	1.13E+02	9.97E+01	5.69E-01	4.59E-01	1.59E-01	1.36E-02	2.14E-04	5.60E-07
5.91E+01	1.12E+02	1.20E+02	1.02E+02	5.53E-01	4.45E-01	1.55E-01	1.32E-02	2.12E-04	5.64E-07
6.29E+01	1.16E+02	1.27E+02	1.05E+02	5.33E-01	4.29E-01	1.49E-01	1.28E-02	2.08E-04	5.66E-07
6.73E+01	1.19E+02	1.35E+02	1.08E+02	5.11E-01	4.10E-01	1.42E-01	1.23E-02	2.02E-04	5.64E-07
7.22E+01	1.23E+02	1.42E+02	1.12E+02	4.85E-01	3.89E-01	1.35E-01	1.18E-02	1.96E-04	5.57E-07
7.78E+01	1.28E+02	1.50E+02	1.15E+02	4.57E-01	3.66E-01	1.27E-01	1.11E-02	1.88E-04	5.47E-07
8.42E+01	1.33E+02	1.57E+02	1.19E+02	4.26E-01	3.40E-01	1.18E-01	1.04E-02	1.78E-04	5.32E-07
9.16E+01	1.38E+02	1.65E+02	1.23E+02	3.93E-01	3.14E-01	1.09E-01	9.63E-03	1.68E-04	5.13E-07
9.99E+01	1.45E+02	1.72E+02	1.27E+02	3.58E-01	2.85E-01	9.90E-02	8.83E-03	1.56E-04	4.90E-07
1.09E+02	1.52E+02	1.79E+02	1.31E+02	3.23E-01	2.57E-01	8.91E-02	7.99E-03	1.44E-04	4.63E-07
1.20E+02	1.60E+02	1.85E+02	1.35E+02	2.88E-01	2.29E-01	7.93E-02	7.16E-03	1.31E-04	4.34E-07
1.33E+02	1.69E+02	1.91E+02	1.39E+02	2.54E-01	2.02E-01	6.98E-02	6.35E-03	1.18E-04	4.03E-07
1.47E+02	1.79E+02	1.98E+02	1.44E+02	2.22E-01	1.76E-01	6.08E-02	5.58E-03	1.06E-04	3.72E-07
1.64E+02	1.90E+02	2.03E+02	1.48E+02	1.92E-01	1.52E-01	5.25E-02	4.86E-03	9.39E-05	3.41E-07
1.83E+02	2.03E+02	2.09E+02	1.52E+02	1.65E-01	1.30E-01	4.49E-02	4.19E-03	8.28E-05	3.12E-07
2.05E+02	2.17E+02	2.15E+02	1.56E+02	1.40E-01	1.10E-01	3.81E-02	3.59E-03	7.26E-05	2.84E-07
2.30E+02	2.33E+02	2.21E+02	1.61E+02	1.19E-01	9.30E-02	3.21E-02	3.06E-03	6.33E-05	2.58E-07
2.60E+02	2.51E+02	2.27E+02	1.65E+02	9.96E-02	7.79E-02	2.69E-02	2.59E-03	5.49E-05	2.33E-07
2.93E+02	2.71E+02	2.33E+02	1.69E+02	8.31E-02	6.49E-02	2.24E-02	2.18E-03	4.75E-05	2.11E-07
3.32E+02	2.94E+02	2.40E+02	1.74E+02	6.90E-02	5.37E-02	1.85E-02	1.82E-03	4.10E-05	1.92E-07
3.76E+02	3.19E+02	2.48E+02	1.78E+02	5.70E-02	4.42E-02	1.52E-02	1.52E-03	3.53E-05	1.74E-07
4.27E+02	3.47E+02	2.56E+02	1.83E+02	4.69E-02	3.62E-02	1.25E-02	1.26E-03	3.03E-05	1.58E-07
4.85E+02	3.79E+02	2.65E+02	1.87E+02	3.84E-02	2.95E-02	1.01E-02	1.04E-03	2.60E-05	1.43E-07

5.53E+02	4.15E+02	2.75E+02	1.92E+02
6.30E+02	4.55E+02	2.86E+02	1.97E+02
7.19E+02	5.00E+02	2.98E+02	2.02E+02
8.21E+02	5.60E+02	3.12E+02	2.08E+02
9.38E+02	6.07E+02	3.28E+02	2.13E+02
1.07E+03	6.70E+02	3.46E+02	2.19E+02
1.23E+03	7.41E+02	3.65E+02	2.25E+02
1.40E+03	8.21E+02	3.88E+02	2.32E+02
1.60E+03	9.10E+02	4.13E+02	2.39E+02

3.13E-02	2.40E-02	8.23E-03	8.59E-04	2.22E-05	1.31E-07
2.54E-02	1.94E-02	6.65E-03	7.06E-04	1.90E-05	1.19E-07
2.06E-02	1.57E-02	5.36E-03	5.78E-04	1.63E-05	1.09E-07
1.66E-02	1.26E-02	4.30E-03	4.72E-04	1.39E-06	1.00E-07
1.34E-02	1.01E-02	3.44E-03	3.85E-04	1.18E-05	9.20E-08
1.08E-02	8.06E-03	2.75E-03	3.13E-04	1.01E-05	8.46E-08
8.64E-03	6.43E-03	2.19E-03	2.54E-04	8.57E-06	7.78E-08
6.91E-03	5.12E-03	1.74E-03	2.06E-04	7.28E-06	7.16E-08
6.52E-03	4.06E-03	1.38E-03	1.66E-04	6.18E-06	6.58E-08

1

TIME AVERAGED (TAV = 10. S) VOLUME CONCENTRATION: MAXIMUM CONCENTRATION (VOLUME FRACTION) ALONG CENTERLINE.

DOWNWIND DISTANCE X (M)	HEIGHT Z (M)	MAXIMUM CONCENTRATION C(X,0,Z)	TIME OF MAX CONC (S)	CLOUD DURATION (S)
-3.11E+01	0.	0.	8.51E+01	1.07E+02
-2.49E+01	0.	5.15E-01	7.88E+01	1.07E+02
-1.87E+01	0.	6.37E-01	7.25E+01	1.07E+02
-1.25E+01	0.	7.01E-01	6.61E+01	1.07E+02
-6.23E+00	0.	7.36E-01	5.98E+01	1.07E+02
-4.83E-13	0.	7.49E-01	5.35E+01	1.07E+02
6.23E+00	0.	7.50E-01	5.98E+01	1.07E+02
1.25E+01	0.	7.43E-01	6.61E+01	1.07E+02
1.87E+01	0.	7.31E-01	7.25E+01	1.07E+02
2.49E+01	0.	7.17E-01	7.88E+01	1.07E+02
3.11E+01	0.	7.02E-01	8.51E+01	1.07E+02
3.15E+01	0.	6.99E-01	8.55E+01	1.07E+02
3.20E+01	0.	6.96E-01	8.59E+01	1.07E+02
3.24E+01	0.	6.91E-01	8.64E+01	1.07E+02
3.30E+01	0.	6.86E-01	8.70E+01	1.07E+02
3.36E+01	0.	6.82E-01	8.76E+01	1.07E+02
3.42E+01	0.	6.77E-01	8.83E+01	1.07E+02
3.50E+01	0.	6.71E-01	8.90E+01	1.07E+02
3.59E+01	0.	6.66E-01	8.99E+01	1.07E+02
3.68E+01	0.	6.60E-01	9.09E+01	1.07E+02
3.79E+01	0.	6.54E-01	9.19E+01	1.07E+02
3.91E+01	0.	6.48E-01	9.32E+01	1.07E+02
4.04E+01	0.	6.41E-01	9.45E+01	1.07E+02
4.19E+01	0.	6.33E-01	9.61E+01	1.07E+02
4.36E+01	0.	6.25E-01	9.78E+01	1.07E+02
4.55E+01	0.	6.16E-01	9.97E+01	1.07E+02
4.76E+01	0.	6.07E-01	1.02E+02	1.07E+02
5.00E+01	0.	5.95E-01	1.04E+02	1.07E+02
5.27E+01	0.	5.83E-01	1.07E+02	1.07E+02
5.57E+01	0.	5.69E-01	1.10E+02	1.13E+02
5.91E+01	0.	5.53E-01	1.12E+02	1.20E+02
6.29E+01	0.	5.33E-01	1.16E+02	1.27E+02
6.73E+01	0.	5.11E-01	1.19E+02	1.35E+02
7.22E+01	0.	4.85E-01	1.23E+02	1.42E+02
7.78E+01	0.	4.57E-01	1.28E+02	1.50E+02
8.42E+01	0.	4.26E-01	1.33E+02	1.57E+02
9.16E+01	0.	3.93E-01	1.38E+02	1.65E+02
9.99E+01	0.	3.58E-01	1.45E+02	1.72E+02
1.09E+02	0.	3.23E-01	1.52E+02	1.79E+02
1.20E+02	0.	2.88E-01	1.60E+02	1.85E+02
1.33E+02	0.	2.54E-01	1.69E+02	1.91E+02
1.47E+02	0.	2.22E-01	1.79E+02	1.98E+02
1.64E+02	0.	1.92E-01	1.90E+02	2.03E+02
1.83E+02	0.	1.65E-01	2.03E+02	2.09E+02
2.05E+02	0.	1.40E-01	2.17E+02	2.15E+02
2.30E+02	0.	1.19E-01	2.33E+02	2.21E+02
2.60E+02	0.	9.96E-02	2.51E+02	2.27E+02
2.93E+02	0.	8.31E-02	2.71E+02	2.33E+02
3.32E+02	0.	6.90E-02	2.94E+02	2.40E+02
3.76E+02	0.	5.70E-02	3.19E+02	2.48E+02
4.27E+02	0.	4.69E-02	3.47E+02	2.56E+02
4.85E+02	0.	3.84E-02	3.79E+02	2.65E+02

5.53E+02	0.	3.13E-02	4.15E+02	2.75E+02
6.30E+02	0.	2.54E-02	4.55E+02	2.86E+02
7.19E+02	0.	2.06E-02	5.00E+02	2.98E+02
8.21E+02	0.	1.66E-02	5.50E+02	3.12E+02
9.38E+02	0.	1.34E-02	6.07E+02	3.28E+02
1.07E+03	0.	1.08E-02	6.70E+02	3.46E+02
1.23E+03	0.	8.64E-03	7.41E+02	3.65E+02
1.40E+03	0.	6.91E-03	8.21E+02	3.88E+02
1.60E+03	0.	5.52E-03	9.10E+02	4.13E+02

PROBLEM INPUT

IDSPL	=	1
NCALC	=	1
WMS	=	0.016043
CPS	=	2238.00
TBP	=	111.70
CMEDO	=	0.00
DHE	=	509900.
CPSL	=	3348.60
RHOSL	=	424.10
SPB	=	983.89
SPC	=	0.00
TS	=	111.70
QS	=	117.00
AS	=	657.00
TSD	=	107.
QTIS	=	0.00
HS	=	0.00
TAV	=	10.00
XFFM	=	1000.00
ZP(1)	=	0.00
ZP(2)	=	0.00
ZP(3)	=	0.00
ZP(4)	=	0.00
ZO	=	0.000200
ZA	=	2.88
UA	=	4.00
TA	=	306.00
RH	=	4.60
STAB	=	0.00
ALA	=	0.0000

RELEASE GAS PROPERTIES

MOLECULAR WEIGHT OF SOURCE GAS (KG)	- WMS	=	1.6043E-02
VAPOR HEAT CAPACITY, CONST. P. (J/KG-K)	- CPS	=	2.2380E+03
TEMPERATURE OF SOURCE GAS (K)	- TS	=	1.1170E+02
DENSITY OF SOURCE GAS (KG/M3)	- RHOS	=	1.7503E+00
BOILING POINT TEMPERATURE	- TBP	=	1.1170E+02
LIQUID MASS FRACTION	- CMEDO	=	0.
LIQUID HEAT CAPACITY (J/KG-K)	- CPSL	=	3.3485E+03
HEAT OF VAPORIZATION (J/KG)	- DHE	=	5.0990E+05
LIQUID SOURCE DENSITY (KG/M3)	- RHOSL	=	4.2410E+02
SATURATION PRESSURE CONSTANT	- SPA	=	8.8083E+00
SATURATION PRESSURE CONSTANT (K)	- SPB	=	9.8389E+02
SATURATION PRESSURE CONSTANT (K)	- SPC	=	0.

SPILL CHARACTERISTICS

SPILL TYPE	- IDSPL	=	1
MASS SOURCE RATE (KG/S)	- QS	=	1.1700E+02
CONTINUOUS SOURCE DURATION (S)	- TSD	=	1.0700E+02
CONTINUOUS SOURCE MASS (KG)	- QTCS	=	1.2519E+04
INSTANTANEOUS SOURCE MASS (KG)	- QTIS	=	0.
SOURCE AREA (M2)	- AS	=	6.5700E+02
VERTICAL VAPOR VELOCITY (M/S)	- WS	=	1.0174E-01
SOURCE HALF WIDTH (M)	- BS	=	1.2816E+01
SOURCE HEIGHT (M)	- HS	=	0.
HORIZONTAL VAPOR VELOCITY (M/S)	- US	=	0.

FIELD PARAMETERS

CONCENTRATION AVERAGING TIME (S)	- TAV	=	1.0000E+01
MIXING LAYER HEIGHT (M)	- HMX	=	1.0400E+03
MAXIMUM DOWNWIND DISTRACE (M)	- XFFM	=	1.0000E+03
CONCENTRATION MEASUREMENT HEIGHT (M)	- ZP(1)	=	0.
	- ZP(2)	=	0.
	- ZP(3)	=	0.
	- ZP(4)	=	0.

AMBIENT METEOROLOGICAL PROPERTIES

MOLECULAR WEIGHT OF AMBIENT AIR (KG)	- WMAE	=	2.8933E-02
HEAT CAPACITY OF AMBIENT AIR AT CONST P. (J/KG-K)	- CPAA	=	1.0071E+03
DENSITY OF AMBIENT AIR (KG/M3)	- RHOA	=	1.1523E+00
AMBIENT MEASUREMENT HEIGHT (M)	- ZA	=	2.8800E+00
AMBIENT ATMOSPHERIC PRESSURE (PA=N/M2=J/M3)	- PA	=	1.0132E+05
AMBIENT WIND SPEED (M/S)	- UA	=	4.0000E+00
AMBIENT TEMPERATURE (K)	- TA	=	3.0600E+02
RELATIVE HUMIDITY (PERCENT)	- RH	=	4.6000E+00
AMBIENT FRICTION VELOCITY (M/S)	- UASTR	=	1.7133E-01
ATMOSPHERIC STABILITY CLASS VALUE	- STAB	=	4.0000E+00
INVERSE MONIN-OBUKHOV LENGTH (1/M)	- ALA	=	0.
SURFACE ROUGHNESS HEIGHT (M)	- ZO	=	2.0000E-04

ADDITIONAL PARAMETERS

SUB-STEP MULTIPLIER	- NCALC	=	1
NUMBER OF CALCULATIONAL SUB-STEPS	- NSSM	=	3
ACCELERATION OF GRAVITY (M/S2)	- GRAV	=	9.8066E+00
GAS CONSTANT (J/MOL- K)	- RR	=	8.3143E+00
VON KARMAN CONSTANT	- XK	=	4.1000E-01

1

INSTANTANEOUS SPATIALLY AVERAGED CLOUD PARAMETERS

X	ZC	H	BB	B	BBX	BX	CV	RHO	T	U	UA
-1.28E+01	0.	0.	1.28E+01	1.15E+01	1.28E+01	1.28E+01	0.	1.15E+00	3.06E+02	0.	0.
-1.03E+01	0.	4.77E-01	1.31E+01	1.15E+01	1.43E+01	1.43E+01	6.88E-01	1.40E+00	1.86E+02	1.52E+00	2.71E+00
-7.69E+00	0.	8.18E-01	1.35E+01	1.16E+01	1.58E+01	1.58E+01	6.29E-01	1.42E+00	1.79E+02	1.55E+00	2.99E+00
-5.13E+00	0.	1.12E+00	1.41E+01	1.18E+01	1.73E+01	1.73E+01	6.47E-01	1.42E+00	1.77E+02	1.55E+00	3.14E+00
-2.56E+00	0.	1.38E+00	1.49E+01	1.22E+01	1.88E+01	1.88E+01	6.55E-01	1.43E+00	1.75E+02	1.56E+00	3.23E+00
-2.24E-13	0.	1.59E+00	1.59E+01	1.27E+01	2.03E+01	2.03E+01	6.58E-01	1.43E+00	1.75E+02	1.58E+00	3.30E+00
2.56E+00	0.	1.74E+00	1.71E+01	1.34E+01	2.18E+01	2.18E+01	6.58E-01	1.42E+00	1.75E+02	1.60E+00	3.34E+00
5.13E+00	0.	1.86E+00	1.86E+01	1.43E+01	2.33E+01	2.33E+01	6.56E-01	1.42E+00	1.76E+02	1.63E+00	3.37E+00
7.69E+00	0.	1.94E+00	2.01E+01	1.52E+01	2.48E+01	2.48E+01	6.52E-01	1.42E+00	1.77E+02	1.67E+00	3.39E+00
1.03E+01	0.	1.99E+00	2.17E+01	1.62E+01	2.63E+01	2.63E+01	6.48E-01	1.41E+00	1.78E+02	1.70E+00	3.40E+00
1.28E+01	0.	2.03E+00	2.35E+01	1.72E+01	2.78E+01	2.78E+01	6.43E-01	1.41E+00	1.79E+02	1.74E+00	3.41E+00
1.30E+01	0.	2.02E+00	2.36E+01	1.73E+01	2.80E+01	2.80E+01	6.40E-01	1.41E+00	1.79E+02	1.76E+00	3.41E+00
1.32E+01	0.	2.00E+00	2.37E+01	1.74E+01	2.82E+01	2.82E+01	6.38E-01	1.41E+00	1.80E+02	1.77E+00	3.40E+00
1.34E+01	0.	1.99E+00	2.39E+01	1.75E+01	2.85E+01	2.85E+01	6.36E-01	1.40E+00	1.80E+02	1.78E+00	3.40E+00
1.37E+01	0.	1.97E+00	2.41E+01	1.76E+01	2.88E+01	2.88E+01	6.33E-01	1.40E+00	1.81E+02	1.80E+00	3.39E+00
1.40E+01	0.	1.95E+00	2.43E+01	1.77E+01	2.92E+01	2.92E+01	6.30E-01	1.40E+00	1.81E+02	1.82E+00	3.39E+00
1.44E+01	0.	1.93E+00	2.45E+01	1.78E+01	2.96E+01	2.96E+01	6.26E-01	1.40E+00	1.82E+02	1.84E+00	3.39E+00
1.48E+01	0.	1.90E+00	2.48E+01	1.80E+01	3.01E+01	3.01E+01	6.22E-01	1.39E+00	1.83E+02	1.86E+00	3.38E+00
1.52E+01	0.	1.88E+00	2.51E+01	1.82E+01	3.06E+01	3.06E+01	6.18E-01	1.39E+00	1.84E+02	1.88E+00	3.37E+00
1.58E+01	0.	1.85E+00	2.55E+01	1.84E+01	3.12E+01	3.12E+01	6.13E-01	1.39E+00	1.85E+02	1.91E+00	3.37E+00
1.64E+01	0.	1.83E+00	2.59E+01	1.87E+01	3.19E+01	3.19E+01	6.08E-01	1.38E+00	1.86E+02	1.93E+00	3.36E+00
1.71E+01	0.	1.80E+00	2.64E+01	1.89E+01	3.27E+01	3.27E+01	6.02E-01	1.38E+00	1.87E+02	1.96E+00	3.35E+00
1.79E+01	0.	1.77E+00	2.69E+01	1.92E+01	3.36E+01	3.36E+01	5.95E-01	1.38E+00	1.88E+02	1.99E+00	3.35E+00
1.88E+01	0.	1.73E+00	2.75E+01	1.96E+01	3.47E+01	3.47E+01	5.88E-01	1.37E+00	1.90E+02	2.03E+00	3.34E+00
1.98E+01	0.	1.70E+00	2.81E+01	2.00E+01	3.59E+01	3.59E+01	5.81E-01	1.37E+00	1.91E+02	2.06E+00	3.33E+00
2.10E+01	0.	1.66E+00	2.89E+01	2.05E+01	3.73E+01	3.73E+01	5.72E-01	1.36E+00	1.93E+02	2.10E+00	3.32E+00
2.23E+01	0.	1.63E+00	2.98E+01	2.10E+01	3.88E+01	3.88E+01	5.62E-01	1.36E+00	1.95E+02	2.15E+00	3.31E+00
2.38E+01	0.	1.59E+00	3.07E+01	2.16E+01	4.06E+01	4.06E+01	5.51E-01	1.35E+00	1.97E+02	2.19E+00	3.30E+00
2.56E+01	0.	1.56E+00	3.18E+01	2.22E+01	4.26E+01	4.26E+01	5.39E-01	1.34E+00	2.00E+02	2.24E+00	3.29E+00
2.76E+01	0.	1.53E+00	3.30E+01	2.30E+01	4.50E+01	4.50E+01	5.25E-01	1.33E+00	2.03E+02	2.29E+00	3.28E+00
2.99E+01	0.	1.50E+00	3.43E+01	2.38E+01	4.76E+01	4.76E+01	5.09E-01	1.32E+00	2.06E+02	2.35E+00	3.27E+00
3.25E+01	0.	1.48E+00	3.58E+01	2.46E+01	5.07E+01	5.07E+01	4.91E-01	1.31E+00	2.10E+02	2.41E+00	3.27E+00
3.54E+01	0.	1.47E+00	3.74E+01	2.56E+01	5.41E+01	5.41E+01	4.70E-01	1.30E+00	2.14E+02	2.47E+00	3.26E+00
3.88E+01	0.	1.47E+00	3.91E+01	2.66E+01	5.81E+01	5.81E+01	4.48E-01	1.29E+00	2.19E+02	2.54E+00	3.26E+00
4.27E+01	0.	1.48E+00	4.10E+01	2.77E+01	6.26E+01	6.26E+01	4.24E-01	1.28E+00	2.24E+02	2.61E+00	3.26E+00
4.71E+01	0.	1.50E+00	4.30E+01	2.89E+01	6.78E+01	6.78E+01	3.97E-01	1.27E+00	2.29E+02	2.68E+00	3.27E+00
5.22E+01	0.	1.53E+00	4.52E+01	3.01E+01	7.37E+01	7.37E+01	3.69E-01	1.25E+00	2.35E+02	2.76E+00	3.28E+00
5.80E+01	0.	1.58E+00	4.74E+01	3.14E+01	8.04E+01	8.04E+01	3.39E-01	1.24E+00	2.41E+02	2.83E+00	3.30E+00
6.46E+01	0.	1.65E+00	4.98E+01	3.27E+01	8.82E+01	8.81E+01	3.09E-01	1.23E+00	2.47E+02	2.91E+00	3.32E+00
7.21E+01	0.	1.74E+00	5.23E+01	3.41E+01	9.70E+01	9.69E+01	2.79E-01	1.22E+00	2.53E+02	2.98E+00	3.34E+00
8.08E+01	0.	1.85E+00	5.49E+01	3.55E+01	1.07E+02	1.07E+02	2.49E-01	1.22E+00	2.58E+02	3.06E+00	3.37E+00
9.06E+01	0.	1.98E+00	5.75E+01	3.69E+01	1.18E+02	1.18E+02	2.21E-01	1.21E+00	2.64E+02	3.13E+00	3.40E+00
1.02E+02	0.	2.15E+00	6.03E+01	3.83E+01	1.32E+02	1.32E+02	1.93E-01	1.20E+00	2.69E+02	3.21E+00	3.43E+00
1.16E+02	0.	2.36E+00	6.32E+01	3.98E+01	1.47E+02	1.47E+02	1.68E-01	1.19E+00	2.74E+02	3.28E+00	3.47E+00
1.29E+02	0.	2.61E+00	6.62E+01	4.12E+01	1.64E+02	1.64E+02	1.44E-01	1.18E+00	2.79E+02	3.35E+00	3.52E+00
1.46E+02	0.	2.90E+00	6.93E+01	4.26E+01	1.83E+02	1.83E+02	1.23E-01	1.18E+00	2.83E+02	3.42E+00	3.57E+00
1.65E+02	0.	3.30E+00	7.26E+01	4.41E+01	1.87E+02	1.84E+02	1.03E-01	1.17E+00	2.87E+02	3.51E+00	3.62E+00
1.88E+02	0.	3.78E+00	7.60E+01	4.55E+01	1.90E+02	1.85E+02	8.50E-02	1.17E+00	2.91E+02	3.59E+00	3.68E+00
2.15E+02	0.	4.35E+00	7.96E+01	4.70E+01	1.95E+02	1.86E+02	6.98E-02	1.16E+00	2.93E+02	3.66E+00	3.74E+00
2.45E+02	0.	5.02E+00	8.36E+01	4.84E+01	1.99E+02	1.87E+02	5.68E-02	1.16E+00	2.96E+02	3.74E+00	3.80E+00
2.81E+02	0.	5.81E+00	8.77E+01	4.99E+01	2.04E+02	1.88E+02	4.58E-02	1.16E+00	2.98E+02	3.81E+00	3.87E+00
3.23E+02	0.	6.74E+00	9.21E+01	5.14E+01	2.10E+02	1.89E+02	3.67E-02	1.16E+00	3.00E+02	3.89E+00	3.93E+00
3.72E+02	0.	7.85E+00	9.69E+01	5.29E+01	2.17E+02	1.90E+02	2.92E-02	1.16E+00	3.01E+02	3.96E+00	3.99E+00
4.28E+02	0.	9.15E+00	1.02E+02	5.44E+01	2.25E+02	1.91E+02	2.31E-02	1.16E+00	3.02E+02	4.03E+00	4.06E+00

4.94E+02	0.	1.07E+01	1.08E+02	5.59E+01	2.33E+02	1.92E+02	1.81E-02	1.15E+00	3.03E+02	4.10E+00	4.12E+00
5.71E+02	0.	1.25E+01	1.14E+02	5.74E+01	2.43E+02	1.93E+02	1.41E-02	1.15E+00	3.04E+02	4.17E+00	4.19E+00
6.60E+02	0.	1.46E+01	1.20E+02	5.90E+01	2.53E+02	1.94E+02	1.09E-02	1.16E+00	3.04E+02	4.24E+00	4.26E+00
7.63E+02	0.	1.71E+01	1.27E+02	6.05E+01	2.66E+02	1.95E+02	8.44E-03	1.15E+00	3.05E+02	4.31E+00	4.32E+00
8.82E+02	0.	2.00E+01	1.35E+02	6.20E+01	2.79E+02	1.96E+02	6.47E-03	1.16E+00	3.05E+02	4.38E+00	4.39E+00
1.02E+03	0.	2.33E+01	1.44E+02	6.35E+01	2.96E+02	1.97E+02	4.94E-03	1.16E+00	3.05E+02	4.44E+00	4.45E+00
1.18E+03	0.	2.72E+01	1.53E+02	6.49E+01	3.13E+02	1.98E+02	3.76E-03	1.16E+00	3.05E+02	4.51E+00	4.61E+00

0 1

1

X	CM	CMV	CMDA	CMW	CMWV	WC	VG	UG	W	V	VX
-1.28E+01	0.	0.	9.98E-01	1.52E-03	1.52E-03	0.	0.	0.	3.95E-01	1.30E-01	0.
-1.03E+01	4.42E-01	4.42E-01	5.57E-01	8.46E-04	4.11E-07	0.	3.10E-02	0.	7.50E-02	1.20E-01	2.53E-01
-7.69E+00	4.85E-01	4.85E-01	5.14E-01	7.80E-04	1.37E-07	0.	1.04E-01	0.	6.24E-02	1.38E-01	2.53E-01
-5.13E+00	5.04E-01	5.04E-01	4.95E-01	7.52E-04	8.53E-08	0.	2.10E-01	0.	5.60E-02	1.48E-01	2.53E-01
-2.56E+00	5.13E-01	5.13E-01	4.87E-01	7.38E-04	6.90E-08	0.	3.37E-01	0.	5.22E-02	1.54E-01	2.54E-01
-2.24E-13	5.16E-01	5.16E-01	4.83E-01	7.33E-04	6.49E-08	0.	4.72E-01	0.	4.99E-02	1.58E-01	2.54E-01
2.56E+00	5.16E-01	5.16E-01	4.83E-01	7.33E-04	6.72E-08	0.	6.02E-01	0.	4.85E-02	1.60E-01	2.54E-01
5.13E+00	5.14E-01	5.14E-01	4.86E-01	7.37E-04	7.41E-08	0.	7.21E-01	0.	4.76E-02	1.60E-01	2.54E-01
7.69E+00	5.10E-01	5.10E-01	4.89E-01	7.43E-04	8.53E-08	0.	8.22E-01	0.	4.70E-02	1.59E-01	2.54E-01
1.03E+01	5.05E-01	5.05E-01	4.94E-01	7.50E-04	1.01E-07	0.	9.06E-01	0.	4.67E-02	1.58E-01	2.54E-01
1.28E+01	5.00E-01	5.00E-01	5.00E-01	7.58E-04	1.22E-07	0.	9.73E-01	0.	4.65E-02	1.57E-01	2.54E-01
1.30E+01	4.97E-01	4.97E-01	5.02E-01	7.62E-04	1.33E-07	0.	9.79E-01	0.	4.63E-02	1.56E-01	2.54E-01
1.32E+01	4.94E-01	4.94E-01	5.05E-01	7.66E-04	1.43E-07	0.	9.88E-01	0.	4.60E-02	1.55E-01	2.54E-01
1.34E+01	4.92E-01	4.92E-01	5.08E-01	7.70E-04	1.56E-07	0.	9.97E-01	0.	4.56E-02	1.54E-01	2.54E-01
1.37E+01	4.89E-01	4.89E-01	5.11E-01	7.75E-04	1.72E-07	0.	1.01E+00	0.	4.48E-02	1.53E-01	2.54E-01
1.40E+01	4.85E-01	4.85E-01	5.14E-01	7.80E-04	1.92E-07	0.	1.02E+00	0.	4.39E-02	1.51E-01	2.54E-01
1.44E+01	4.81E-01	4.81E-01	5.18E-01	7.86E-04	2.16E-07	0.	1.03E+00	0.	4.28E-02	1.50E-01	2.54E-01
1.48E+01	4.77E-01	4.77E-01	5.22E-01	7.92E-04	2.47E-07	0.	1.04E+00	0.	4.15E-02	1.49E-01	2.54E-01
1.52E+01	4.72E-01	4.72E-01	5.27E-01	7.99E-04	2.85E-07	0.	1.05E+00	0.	4.01E-02	1.47E-01	2.54E-01
1.58E+01	4.67E-01	4.67E-01	5.32E-01	8.07E-04	3.33E-07	0.	1.07E+00	0.	3.87E-02	1.46E-01	2.54E-01
1.64E+01	4.62E-01	4.62E-01	5.37E-01	8.15E-04	3.94E-07	0.	1.08E+00	0.	3.73E-02	1.44E-01	2.54E-01
1.71E+01	4.56E-01	4.56E-01	5.43E-01	8.24E-04	4.74E-07	0.	1.10E+00	0.	3.60E-02	1.42E-01	2.54E-01
1.79E+01	4.49E-01	4.49E-01	5.50E-01	8.34E-04	5.78E-07	0.	1.11E+00	0.	3.50E-02	1.40E-01	2.54E-01
1.88E+01	4.42E-01	4.42E-01	5.57E-01	8.45E-04	7.19E-07	0.	1.13E+00	0.	3.41E-02	1.38E-01	2.54E-01
1.98E+01	4.34E-01	4.34E-01	5.65E-01	8.57E-04	9.12E-07	0.	1.14E+00	0.	3.36E-02	1.35E-01	2.54E-01
2.10E+01	4.26E-01	4.26E-01	5.74E-01	8.70E-04	1.18E-06	0.	1.15E+00	0.	3.35E-02	1.33E-01	2.54E-01
2.23E+01	4.16E-01	4.16E-01	5.83E-01	8.85E-04	1.58E-06	0.	1.16E+00	0.	3.36E-02	1.30E-01	2.54E-01
2.38E+01	4.05E-01	4.05E-01	5.94E-01	9.01E-04	2.17E-06	0.	1.17E+00	0.	3.40E-02	1.27E-01	2.54E-01
2.56E+01	3.93E-01	3.93E-01	6.06E-01	9.20E-04	3.10E-06	0.	1.17E+00	0.	3.46E-02	1.24E-01	2.54E-01
2.76E+01	3.80E-01	3.80E-01	6.20E-01	9.40E-04	4.57E-06	0.	1.17E+00	0.	3.53E-02	1.21E-01	2.54E-01
2.99E+01	3.65E-01	3.65E-01	6.34E-01	9.63E-04	7.01E-06	0.	1.17E+00	0.	3.62E-02	1.18E-01	2.54E-01
3.25E+01	3.48E-01	3.48E-01	6.51E-01	9.88E-04	1.12E-05	0.	1.16E+00	0.	3.71E-02	1.15E-01	2.54E-01
3.54E+01	3.30E-01	3.30E-01	6.69E-01	1.02E-03	1.85E-05	0.	1.13E+00	0.	3.82E-02	1.12E-01	2.54E-01
3.88E+01	3.10E-01	3.10E-01	6.88E-01	1.04E-03	3.15E-05	0.	1.10E+00	0.	3.92E-02	1.09E-01	2.54E-01
4.27E+01	2.90E-01	2.90E-01	7.09E-01	1.08E-03	5.50E-05	0.	1.06E+00	0.	4.04E-02	1.06E-01	2.54E-01
4.71E+01	2.68E-01	2.68E-01	7.31E-01	1.11E-03	9.76E-05	0.	1.01E+00	0.	4.15E-02	1.03E-01	2.54E-01
5.22E+01	2.45E-01	2.45E-01	7.54E-01	1.14E-03	1.73E-04	0.	9.58E-01	0.	4.27E-02	1.01E-01	2.54E-01
5.80E+01	2.22E-01	2.22E-01	7.77E-01	1.18E-03	3.03E-04	0.	9.00E-01	0.	4.38E-02	9.90E-02	2.54E-01
6.46E+01	1.99E-01	1.99E-01	8.00E-01	1.21E-03	5.15E-04	0.	8.38E-01	0.	4.48E-02	9.74E-02	2.54E-01
7.21E+01	1.76E-01	1.76E-01	8.22E-01	1.25E-03	8.35E-04	0.	7.76E-01	0.	4.54E-02	9.61E-02	2.54E-01
8.08E+01	1.55E-01	1.55E-01	8.43E-01	1.28E-03	1.28E-03	0.	7.15E-01	0.	4.56E-02	9.51E-02	2.54E-01
9.06E+01	1.36E-01	1.36E-01	8.63E-01	1.31E-03	1.31E-03	0.	6.56E-01	0.	4.69E-02	9.44E-02	2.54E-01
1.02E+02	1.17E-01	1.17E-01	8.81E-01	1.34E-03	1.34E-03	0.	5.99E-01	0.	4.83E-02	9.40E-02	2.54E-01
1.15E+02	1.01E-01	1.01E-01	8.98E-01	1.36E-03	1.36E-03	0.	5.44E-01	0.	4.97E-02	9.38E-02	2.54E-01
1.29E+02	8.55E-02	8.55E-02	9.13E-01	1.39E-03	1.39E-03	0.	4.93E-01	0.	5.12E-02	9.37E-02	2.54E-01
1.46E+02	7.22E-02	7.22E-02	9.26E-01	1.41E-03	1.41E-03	0.	4.46E-01	1.69E-01	5.26E-02	9.39E-02	2.54E-01
1.65E+02	5.97E-02	5.97E-02	9.39E-01	1.42E-03	1.42E-03	0.	3.98E-01	1.51E-01	5.40E-02	9.42E-02	2.60E-01
1.88E+02	4.90E-02	4.90E-02	9.50E-01	1.44E-03	1.44E-03	0.	3.56E-01	1.36E-01	5.56E-02	9.46E-02	2.60E-01
2.15E+02	3.99E-02	3.99E-02	9.59E-01	1.45E-03	1.45E-03	0.	3.18E-01	1.22E-01	5.70E-02	9.51E-02	2.61E-01
2.45E+02	3.23E-02	3.23E-02	9.66E-01	1.47E-03	1.47E-03	0.	2.85E-01	1.11E-01	5.86E-02	9.56E-02	2.61E-01
2.81E+02	2.59E-02	2.59E-02	9.73E-01	1.48E-03	1.48E-03	0.	2.56E-01	1.01E-01	6.02E-02	9.60E-02	2.61E-01
3.23E+02	2.07E-02	2.07E-02	9.78E-01	1.48E-03	1.48E-03	0.	2.30E-01	9.17E-02	6.19E-02	9.64E-02	2.61E-01
3.72E+02	1.64E-02	1.64E-02	9.82E-01	1.49E-03	1.49E-03	0.	2.07E-01	8.38E-02	6.36E-02	9.67E-02	2.61E-01
4.28E+02	1.29E-02	1.29E-02	9.86E-01	1.50E-03	1.50E-03	0.	1.87E-01	7.68E-02	6.52E-02	9.69E-02	2.61E-01
4.94E+02	1.01E-02	1.01E-02	9.88E-01	1.50E-03	1.50E-03	0.	1.69E-01	7.04E-02	6.69E-02	9.71E-02	2.61E-01
5.71E+02	7.88E-03	7.88E-03	9.91E-01	1.50E-03	1.50E-03	0.	1.52E-01	6.46E-02	6.85E-02	9.71E-02	2.60E-01
6.60E+02	6.10E-03	6.10E-03	9.92E-01	1.51E-03	1.51E-03	0.	1.37E-01	5.91E-02	7.00E-02	9.70E-02	2.60E-01

7.63E+02	4.70E-03	4.70E-03	9.94E-01	1.51E-03	1.51E-03	0.	1.23E-01	5.40E-02	7.14E-02	9.67E-02	2.60E-01
8.82E+02	3.60E-03	3.60E-03	9.95E-01	1.51E-03	1.51E-03	0.	1.11E-01	4.92E-02	7.26E-02	9.64E-02	2.59E-01
1.02E+03	2.74E-03	2.74E-03	9.96E-01	1.51E-03	1.51E-03	0.	9.90E-02	4.47E-02	7.37E-02	9.58E-02	2.59E-01
1.18E+03	2.08E-03	2.08E-03	9.96E-01	1.51E-03	1.51E-03	0.	8.83E-02	4.03E-02	7.46E-02	9.51E-02	2.58E-01

1

TIME AVERAGED (TAV = 10. S) VOLUME CONCENTRATION: CONCENTRATION CONTOUR PARAMETERS

C(X,Y,Z,T) = CC(X) * (ERF(XA)-ERF(XB)) * (ERF(YA)-ERF(YB)) * (EXP(-ZA*ZA)+EXP(-ZB*ZB))

C(X,Y,Z,T) = CONCENTRATION (VOLUME FRACTION) AT (X,Y,Z,T)
X = DOWNWIND DISTANCE (M)
Y = CROSSWIND HORIZONTAL DISTANCE (M)
Z = HEIGHT (M)
T = TIME (S)

ERF = ERROR FUNCTON
XA = (X-XC+BX)/(SR2*BETAX)
XB = (X-XC-BX)/(SR2*BETAX)
YA = (Y+B)/(SR2*BETAC)
YB = (Y-B)/(SR2*BETAC)
EXP = EXPONENTIAL FUNCTION
ZA = (Z-ZC)/(SR2*SIG)
ZB = (Z+ZC)/(SR2*SIG)
SR2 = SQRT(2.0)

X	CC(X)	B(X)	BETAC(X)	ZC(X)	SIG(X)
-1.28E+01	0.	1.15E+01	3.23E+00	0.	0.
-1.03E+01	1.15E-01	1.15E+01	3.55E+00	0.	2.75E-01
-7.69E+00	1.26E-01	1.16E+01	3.95E+00	0.	4.72E-01
-5.13E+00	1.33E-01	1.18E+01	4.39E+00	0.	6.47E-01
-2.56E+00	1.38E-01	1.22E+01	4.90E+00	0.	7.96E-01
-2.24E-13	1.42E-01	1.27E+01	5.47E+00	0.	9.16E-01
2.56E+00	1.45E-01	1.34E+01	6.12E+00	0.	1.01E+00
5.13E+00	1.47E-01	1.43E+01	6.83E+00	0.	1.07E+00
7.69E+00	1.49E-01	1.52E+01	7.59E+00	0.	1.12E+00
1.03E+01	1.51E-01	1.62E+01	8.39E+00	0.	1.15E+00
1.28E+01	1.52E-01	1.72E+01	9.22E+00	0.	1.17E+00
1.30E+01	1.51E-01	1.73E+01	9.28E+00	0.	1.17E+00
1.32E+01	1.51E-01	1.74E+01	9.35E+00	0.	1.16E+00
1.34E+01	1.50E-01	1.75E+01	9.43E+00	0.	1.15E+00
1.37E+01	1.50E-01	1.76E+01	9.51E+00	0.	1.14E+00
1.40E+01	1.49E-01	1.77E+01	9.62E+00	0.	1.13E+00
1.44E+01	1.49E-01	1.78E+01	9.73E+00	0.	1.11E+00
1.48E+01	1.48E-01	1.80E+01	9.86E+00	0.	1.10E+00
1.52E+01	1.47E-01	1.82E+01	1.00E+01	0.	1.09E+00
1.58E+01	1.47E-01	1.84E+01	1.02E+01	0.	1.07E+00
1.64E+01	1.46E-01	1.87E+01	1.04E+01	0.	1.05E+00
1.71E+01	1.45E-01	1.89E+01	1.06E+01	0.	1.04E+00
1.79E+01	1.44E-01	1.92E+01	1.08E+01	0.	1.02E+00
1.88E+01	1.42E-01	1.96E+01	1.11E+01	0.	9.99E-01
1.98E+01	1.41E-01	2.00E+01	1.14E+01	0.	9.79E-01
2.10E+01	1.39E-01	2.05E+01	1.18E+01	0.	9.59E-01
2.23E+01	1.38E-01	2.10E+01	1.22E+01	0.	9.38E-01
2.38E+01	1.36E-01	2.16E+01	1.26E+01	0.	9.18E-01
2.56E+01	1.33E-01	2.22E+01	1.31E+01	0.	9.00E-01
2.76E+01	1.30E-01	2.30E+01	1.37E+01	0.	8.83E-01
2.99E+01	1.27E-01	2.38E+01	1.43E+01	0.	8.68E-01
3.25E+01	1.23E-01	2.46E+01	1.50E+01	0.	8.57E-01
3.54E+01	1.19E-01	2.56E+01	1.57E+01	0.	8.49E-01
3.88E+01	1.14E-01	2.66E+01	1.66E+01	0.	8.47E-01
4.27E+01	1.08E-01	2.77E+01	1.75E+01	0.	8.52E-01
4.71E+01	1.02E-01	2.89E+01	1.84E+01	0.	8.63E-01
5.22E+01	9.55E-02	3.01E+01	1.94E+01	0.	8.83E-01

T	XC(T)	BX(T)	BETAX(T)
4.12E+00	0.	1.28E+01	1.05E-01
5.01E+00	1.28E+00	1.43E+01	1.17E-01
5.90E+00	2.56E+00	1.58E+01	1.29E-01
6.93E+00	3.84E+00	1.73E+01	1.41E-01
7.96E+00	5.13E+00	1.88E+01	1.53E-01
9.13E+00	6.41E+00	2.03E+01	1.66E-01
1.03E+01	7.69E+00	2.18E+01	1.78E-01
1.16E+01	8.97E+00	2.33E+01	1.90E-01
1.29E+01	1.03E+01	2.48E+01	2.02E-01
1.43E+01	1.15E+01	2.63E+01	2.14E-01
1.57E+01	1.28E+01	2.78E+01	2.27E-01
1.59E+01	1.30E+01	2.80E+01	2.28E-01
1.62E+01	1.32E+01	2.82E+01	2.30E-01
1.64E+01	1.34E+01	2.85E+01	2.33E-01
1.67E+01	1.37E+01	2.88E+01	2.35E-01
1.71E+01	1.40E+01	2.92E+01	2.38E-01
1.75E+01	1.44E+01	2.96E+01	2.42E-01
1.79E+01	1.48E+01	3.01E+01	2.45E-01
1.84E+01	1.52E+01	3.06E+01	2.50E-01
1.89E+01	1.58E+01	3.12E+01	2.55E-01
1.96E+01	1.64E+01	3.19E+01	2.61E-01
2.03E+01	1.71E+01	3.27E+01	2.67E-01
2.11E+01	1.79E+01	3.36E+01	2.75E-01
2.20E+01	1.88E+01	3.47E+01	2.83E-01
2.30E+01	1.98E+01	3.59E+01	2.93E-01
2.41E+01	2.10E+01	3.73E+01	3.04E-01
2.54E+01	2.23E+01	3.88E+01	3.17E-01
2.68E+01	2.38E+01	4.06E+01	3.32E-01
2.84E+01	2.56E+01	4.26E+01	3.48E-01
3.01E+01	2.76E+01	4.50E+01	3.67E-01
3.21E+01	2.99E+01	4.76E+01	3.89E-01
3.43E+01	3.25E+01	5.07E+01	4.14E-01
3.67E+01	3.54E+01	5.41E+01	4.42E-01
3.94E+01	3.88E+01	5.81E+01	4.74E-01
4.24E+01	4.27E+01	6.26E+01	5.11E-01
4.58E+01	4.71E+01	6.78E+01	5.54E-01
4.95E+01	5.22E+01	7.37E+01	6.02E-01

5.80E+01	8.85E-02	3.14E+01	2.05E+01	0.	9.12E-01	5.36E+01	5.80E+01	8.04E+01	6.57E-01
6.46E+01	8.12E-02	3.27E+01	2.17E+01	0.	9.52E-01	5.82E+01	6.46E+01	8.81E+01	7.20E-01
7.21E+01	7.38E-02	3.41E+01	2.29E+01	0.	1.00E+00	6.34E+01	7.21E+01	9.69E+01	7.92E-01
8.08E+01	6.65E-02	3.55E+01	2.42E+01	0.	1.07E+00	6.91E+01	8.08E+01	1.07E+02	8.74E-01
9.06E+01	5.94E-02	3.69E+01	2.55E+01	0.	1.15E+00	7.54E+01	9.06E+01	1.18E+02	9.67E-01
1.02E+02	5.26E-02	3.83E+01	2.69E+01	0.	1.24E+00	8.25E+01	1.02E+02	1.32E+02	1.07E+00
1.15E+02	4.61E-02	3.98E+01	2.84E+01	0.	1.36E+00	9.04E+01	1.15E+02	1.47E+02	1.20E+00
1.29E+02	4.01E-02	4.12E+01	2.99E+01	0.	1.50E+00	9.93E+01	1.29E+02	1.64E+02	1.34E+00
1.46E+02	3.46E-02	4.26E+01	3.16E+01	0.	1.67E+00	1.09E+02	1.46E+02	1.83E+02	1.50E+00
1.65E+02	2.96E-02	4.41E+01	3.33E+01	0.	1.91E+00	1.13E+02	1.65E+02	1.84E+02	1.75E+01
1.88E+02	2.52E-02	4.55E+01	3.51E+01	0.	2.18E+00	1.19E+02	1.88E+02	1.85E+02	2.59E+01
2.15E+02	2.14E-02	4.70E+01	3.71E+01	0.	2.51E+00	1.26E+02	2.15E+02	1.86E+02	3.31E+01
2.45E+02	1.80E-02	4.84E+01	3.93E+01	0.	2.90E+00	1.35E+02	2.45E+02	1.87E+02	4.00E+01
2.81E+02	1.51E-02	4.99E+01	4.16E+01	0.	3.35E+00	1.44E+02	2.81E+02	1.88E+02	4.68E+01
3.23E+02	1.27E-02	5.14E+01	4.41E+01	0.	3.89E+00	1.55E+02	3.23E+02	1.89E+02	5.37E+01
3.72E+02	1.06E-02	5.29E+01	4.69E+01	0.	4.53E+00	1.67E+02	3.72E+02	1.90E+02	6.10E+01
4.28E+02	8.80E-03	5.44E+01	4.98E+01	0.	5.28E+00	1.82E+02	4.28E+02	1.91E+02	6.86E+01
4.94E+02	7.32E-03	5.59E+01	5.31E+01	0.	6.17E+00	1.98E+02	4.94E+02	1.92E+02	7.66E+01
5.71E+02	6.08E-03	5.74E+01	5.66E+01	0.	7.21E+00	2.16E+02	5.71E+02	1.93E+02	8.52E+01
6.60E+02	5.05E-03	5.90E+01	6.05E+01	0.	8.43E+00	2.37E+02	6.60E+02	1.94E+02	9.44E+01
7.63E+02	4.19E-03	6.05E+01	6.48E+01	0.	9.85E+00	2.61E+02	7.63E+02	1.95E+02	1.04E+02
8.82E+02	3.48E-03	6.20E+01	6.94E+01	0.	1.15E+01	2.89E+02	8.82E+02	1.96E+02	1.16E+02
1.02E+03	2.90E-03	6.35E+01	7.45E+01	0.	1.35E+01	3.20E+02	1.02E+03	1.97E+02	1.27E+02
1.18E+03	2.42E-03	6.49E+01	8.01E+01	0.	1.67E+01	3.56E+02	1.18E+03	1.98E+02	1.40E+02

1

TIME AVERAGED (TAV = 10. S) VOLUME CONCENTRATION: CONCENTRATION IN THE Z = 0.00 PLANE.

DOWNWIND DISTANCE X (M)	TIME OF MAX CONC (S)	CLOUD DURATION (S)	EFFECTIVE HALF WIDTH BBC (M)	AVERAGE CONCENTRATION (VOLUME FRACTION) AT (X,Y,Z) Y/BBC= 0.0	Y/BBC= 0.5	Y/BBC= 1.0	Y/BBC= 1.5	Y/BBC= 2.0	Y/BBC= 2.5
-1.28E+01	5.82E+01	1.07E+02	1.28E+01	0.	0.	0.	0.	0.	0.
-1.03E+01	5.73E+01	1.07E+02	1.31E+01	9.20E-01	8.48E-01	3.06E-01	1.06E-02	1.81E-05	1.23E-09
-7.69E+00	5.63E+01	1.07E+02	1.35E+01	1.00E+00	9.00E-01	3.22E-01	1.48E-02	5.09E-05	1.10E-08
-5.13E+00	5.54E+01	1.07E+02	1.41E+01	1.00E+00	9.17E-01	3.25E-01	1.86E-02	1.09E-04	5.65E-08
-2.56E+00	5.44E+01	1.07E+02	1.49E+01	1.00E+00	9.20E-01	3.24E-01	2.17E-02	1.90E-04	1.81E-07
-2.24E-13	5.36E+01	1.07E+02	1.59E+01	1.00E+00	9.18E-01	3.21E-01	2.43E-02	2.89E-04	4.73E-07
2.56E+00	5.44E+01	1.07E+02	1.71E+01	1.00E+00	9.11E-01	3.17E-01	2.64E-02	3.94E-04	9.39E-07
5.13E+00	5.54E+01	1.07E+02	1.85E+01	1.00E+00	9.04E-01	3.13E-01	2.80E-02	4.98E-04	1.58E-06
7.69E+00	5.63E+01	1.07E+02	2.01E+01	1.00E+00	8.95E-01	3.09E-01	2.92E-02	5.96E-04	2.37E-06
1.03E+01	5.73E+01	1.07E+02	2.17E+01	1.00E+00	8.85E-01	3.05E-01	3.02E-02	6.84E-04	3.24E-06
1.28E+01	5.82E+01	1.07E+02	2.35E+01	1.00E+00	8.76E-01	3.01E-01	3.08E-02	7.63E-04	4.16E-06
1.30E+01	5.83E+01	1.07E+02	2.36E+01	1.00E+00	8.72E-01	3.00E-01	3.08E-02	7.66E-04	4.22E-06
1.32E+01	5.83E+01	1.07E+02	2.37E+01	1.00E+00	8.69E-01	2.98E-01	3.07E-02	7.69E-04	4.28E-06
1.34E+01	5.84E+01	1.07E+02	2.39E+01	1.00E+00	8.65E-01	2.97E-01	3.07E-02	7.73E-04	4.35E-06
1.37E+01	5.85E+01	1.07E+02	2.41E+01	1.00E+00	8.61E-01	2.96E-01	3.06E-02	7.78E-04	4.43E-06
1.40E+01	5.86E+01	1.07E+02	2.43E+01	1.00E+00	8.57E-01	2.94E-01	3.05E-02	7.82E-04	4.52E-06
1.44E+01	5.88E+01	1.07E+02	2.45E+01	1.00E+00	8.51E-01	2.92E-01	3.05E-02	7.88E-04	4.61E-06
1.48E+01	5.89E+01	1.07E+02	2.48E+01	1.00E+00	8.46E-01	2.90E-01	3.04E-02	7.93E-04	4.72E-06
1.52E+01	5.91E+01	1.07E+02	2.51E+01	1.00E+00	8.39E-01	2.88E-01	3.03E-02	7.99E-04	4.85E-06
1.58E+01	5.93E+01	1.07E+02	2.55E+01	1.00E+00	8.33E-01	2.85E-01	3.02E-02	8.06E-04	4.98E-06
1.64E+01	5.95E+01	1.07E+02	2.59E+01	1.00E+00	8.25E-01	2.83E-01	3.00E-02	8.13E-04	5.13E-06
1.71E+01	5.98E+01	1.07E+02	2.64E+01	1.00E+00	8.17E-01	2.80E-01	2.99E-02	8.20E-04	5.30E-06
1.79E+01	6.00E+01	1.07E+02	2.69E+01	1.00E+00	8.08E-01	2.76E-01	2.97E-02	8.28E-04	5.48E-06
1.88E+01	6.04E+01	1.07E+02	2.75E+01	1.00E+00	7.98E-01	2.73E-01	2.95E-02	8.36E-04	5.68E-06
1.98E+01	6.07E+01	1.07E+02	2.81E+01	1.00E+00	7.87E-01	2.69E-01	2.93E-02	8.43E-04	5.89E-06
2.10E+01	6.12E+01	1.07E+02	2.89E+01	1.00E+00	7.74E-01	2.65E-01	2.90E-02	8.50E-04	6.11E-06
2.23E+01	6.17E+01	1.07E+02	2.98E+01	1.00E+00	7.61E-01	2.60E-01	2.87E-02	8.57E-04	6.35E-06
2.38E+01	6.22E+01	1.07E+02	3.07E+01	9.89E-01	7.45E-01	2.54E-01	2.83E-02	8.62E-04	6.59E-06
2.56E+01	6.29E+01	1.07E+02	3.18E+01	9.69E-01	7.28E-01	2.48E-01	2.79E-02	8.65E-04	6.83E-06
2.76E+01	6.36E+01	1.07E+02	3.30E+01	9.45E-01	7.08E-01	2.41E-01	2.73E-02	8.65E-04	7.07E-06
2.99E+01	6.44E+01	1.07E+02	3.43E+01	9.17E-01	6.86E-01	2.34E-01	2.67E-02	8.62E-04	7.29E-06
3.25E+01	6.54E+01	1.07E+02	3.58E+01	8.86E-01	6.61E-01	2.25E-01	2.59E-02	8.55E-04	7.48E-06
3.54E+01	6.65E+01	1.07E+02	3.74E+01	8.51E-01	6.34E-01	2.15E-01	2.50E-02	8.44E-04	7.65E-06
3.88E+01	6.77E+01	1.07E+02	3.91E+01	8.12E-01	6.03E-01	2.05E-01	2.40E-02	8.27E-04	7.77E-06
4.27E+01	6.91E+01	1.07E+02	4.10E+01	7.69E-01	5.70E-01	1.93E-01	2.29E-02	8.04E-04	7.83E-06
4.71E+01	7.08E+01	1.07E+02	4.30E+01	7.22E-01	5.33E-01	1.81E-01	2.16E-02	7.76E-04	7.83E-06
5.22E+01	7.26E+01	1.07E+02	4.52E+01	6.72E-01	4.95E-01	1.68E-01	2.02E-02	7.42E-04	7.76E-06
5.80E+01	7.47E+01	1.07E+02	4.74E+01	6.19E-01	4.55E-01	1.54E-01	1.87E-02	7.02E-04	7.62E-06
6.46E+01	7.72E+01	1.07E+02	4.98E+01	5.64E-01	4.14E-01	1.40E-01	1.71E-02	6.59E-04	7.41E-06
7.21E+01	7.99E+01	1.07E+02	5.23E+01	5.10E-01	3.73E-01	1.26E-01	1.56E-02	6.12E-04	7.14E-06
8.08E+01	8.31E+01	1.07E+02	5.49E+01	4.56E-01	3.33E-01	1.12E-01	1.40E-02	5.63E-04	6.83E-06
9.06E+01	8.67E+01	1.07E+02	5.75E+01	4.05E-01	2.95E-01	9.93E-02	1.25E-02	5.14E-04	6.48E-06
1.02E+02	9.08E+01	1.07E+02	6.03E+01	3.56E-01	2.58E-01	8.69E-02	1.10E-02	4.65E-04	6.08E-06
1.15E+02	9.55E+01	1.07E+02	6.32E+01	3.09E-01	2.24E-01	7.52E-02	9.64E-03	4.16E-04	5.66E-06
1.29E+02	1.01E+02	1.07E+02	6.62E+01	2.66E-01	1.92E-01	6.45E-02	8.35E-03	3.69E-04	5.23E-06
1.46E+02	1.07E+02	1.07E+02	6.93E+01	2.28E-01	1.64E-01	5.49E-02	7.17E-03	3.25E-04	4.80E-06
1.65E+02	1.13E+02	1.07E+02	7.26E+01	1.93E-01	1.39E-01	4.64E-02	6.12E-03	2.84E-04	4.37E-06
1.88E+02	1.19E+02	1.07E+02	7.60E+01	1.62E-01	1.16E-01	3.89E-02	5.18E-03	2.47E-04	3.97E-06
2.15E+02	1.26E+02	1.07E+02	7.96E+01	1.36E-01	9.69E-02	3.24E-02	4.35E-03	2.13E-04	3.58E-06
2.45E+02	1.35E+02	1.07E+02	8.35E+01	1.13E-01	8.03E-02	2.68E-02	3.64E-03	1.83E-04	3.21E-06
2.81E+02	1.44E+02	1.07E+02	8.77E+01	9.32E-02	6.61E-02	2.20E-02	3.02E-03	1.56E-04	2.87E-06
3.23E+02	1.55E+02	1.08E+02	9.21E+01	7.65E-02	5.41E-02	1.80E-02	2.49E-03	1.32E-04	2.55E-06

3.72E+02	1.67E+02	1.10E+02	9.69E+01
4.28E+02	1.82E+02	1.11E+02	1.02E+02
4.94E+02	1.98E+02	1.14E+02	1.08E+02
5.71E+02	2.16E+02	1.16E+02	1.14E+02
6.60E+02	2.37E+02	1.19E+02	1.20E+02
7.63E+02	2.61E+02	1.23E+02	1.27E+02
8.82E+02	2.89E+02	1.28E+02	1.35E+02
1.02E+03	3.20E+02	1.33E+02	1.44E+02
1.18E+03	3.56E+02	1.39E+02	1.53E+02

6.25E-02	4.41E-02	1.46E-02	2.05E-03	1.12E-04	2.26E-06
5.07E-02	3.57E-02	1.18E-02	1.67E-03	9.35E-05	1.98E-06
4.09E-02	2.87E-02	9.47E-03	1.35E-03	7.77E-05	1.72E-06
3.27E-02	2.29E-02	7.64E-03	1.09E-03	6.40E-05	1.48E-06
2.59E-02	1.81E-02	5.96E-03	8.65E-04	5.22E-05	1.26E-06
2.04E-02	1.42E-02	4.67E-03	6.83E-04	4.21E-05	1.06E-06
1.59E-02	1.11E-02	3.63E-03	5.35E-04	3.37E-05	8.77E-07
1.23E-02	8.54E-03	2.80E-03	4.15E-04	2.67E-05	7.20E-07
9.46E-03	6.56E-03	2.15E-03	3.20E-04	2.09E-05	5.83E-07

0

1

TIME AVERAGED (TAV = 10. S) VOLUME CONCENTRATION: MAXIMUM CONCENTRATION (VOLUME FRACTION) ALONG CENTERLINE.

DOWNWIND DISTANCE X (M)	HEIGHT Z (M)	MAXIMUM CONCENTRATION C(X,0,Z)	TIME OF MAX CONC (S)	CLOUD DURATION (S)
-1.28E+01	0.	0.	5.82E+01	1.07E+02
-1.03E+01	0.	9.20E-01	5.73E+01	1.07E+02
-7.69E+00	0.	1.00E+00	5.63E+01	1.07E+02
-5.13E+00	0.	1.00E+00	5.54E+01	1.07E+02
-2.56E+00	0.	1.00E+00	5.44E+01	1.07E+02
-2.24E-13	0.	1.00E+00	5.35E+01	1.07E+02
2.56E+00	0.	1.00E+00	5.44E+01	1.07E+02
5.13E+00	0.	1.00E+00	5.54E+01	1.07E+02
7.69E+00	0.	1.00E+00	5.63E+01	1.07E+02
1.03E+01	0.	1.00E+00	5.73E+01	1.07E+02
1.28E+01	0.	1.00E+00	5.82E+01	1.07E+02
1.30E+01	0.	1.00E+00	5.83E+01	1.07E+02
1.32E+01	0.	1.00E+00	5.83E+01	1.07E+02
1.34E+01	0.	1.00E+00	5.84E+01	1.07E+02
1.37E+01	0.	1.00E+00	5.85E+01	1.07E+02
1.40E+01	0.	1.00E+00	5.86E+01	1.07E+02
1.44E+01	0.	1.00E+00	5.88E+01	1.07E+02
1.48E+01	0.	1.00E+00	5.89E+01	1.07E+02
1.52E+01	0.	1.00E+00	5.91E+01	1.07E+02
1.58E+01	0.	1.00E+00	5.93E+01	1.07E+02
1.64E+01	0.	1.00E+00	5.95E+01	1.07E+02
1.71E+01	0.	1.00E+00	5.98E+01	1.07E+02
1.79E+01	0.	1.00E+00	6.00E+01	1.07E+02
1.88E+01	0.	1.00E+00	6.04E+01	1.07E+02
1.98E+01	0.	1.00E+00	6.07E+01	1.07E+02
2.10E+01	0.	1.00E+00	6.12E+01	1.07E+02
2.23E+01	0.	1.00E+00	6.17E+01	1.07E+02
2.38E+01	0.	9.89E-01	6.22E+01	1.07E+02
2.56E+01	0.	9.69E-01	6.29E+01	1.07E+02
2.76E+01	0.	9.45E-01	6.36E+01	1.07E+02
2.99E+01	0.	9.17E-01	6.44E+01	1.07E+02
3.25E+01	0.	8.86E-01	6.54E+01	1.07E+02
3.54E+01	0.	8.51E-01	6.65E+01	1.07E+02
3.88E+01	0.	8.12E-01	6.77E+01	1.07E+02
4.27E+01	0.	7.69E-01	6.91E+01	1.07E+02
4.71E+01	0.	7.22E-01	7.08E+01	1.07E+02
5.22E+01	0.	6.72E-01	7.26E+01	1.07E+02
5.80E+01	0.	6.19E-01	7.47E+01	1.07E+02
6.46E+01	0.	5.64E-01	7.72E+01	1.07E+02
7.21E+01	0.	5.10E-01	7.99E+01	1.07E+02
8.08E+01	0.	4.56E-01	8.31E+01	1.07E+02
9.06E+01	0.	4.05E-01	8.67E+01	1.07E+02
1.02E+02	0.	3.56E-01	9.08E+01	1.07E+02
1.15E+02	0.	3.09E-01	9.55E+01	1.07E+02
1.29E+02	0.	2.66E-01	1.01E+02	1.07E+02
1.46E+02	0.	2.28E-01	1.07E+02	1.07E+02
1.65E+02	0.	1.93E-01	1.13E+02	1.07E+02
1.88E+02	0.	1.62E-01	1.19E+02	1.07E+02
2.15E+02	0.	1.36E-01	1.26E+02	1.07E+02
2.45E+02	0.	1.13E-01	1.35E+02	1.07E+02
2.81E+02	0.	9.32E-02	1.44E+02	1.07E+02
3.23E+02	0.	7.65E-02	1.55E+02	1.08E+02

3.72E+02	0.	6.25E-02	1.67E+02	1.10E+02
4.28E+02	0.	5.07E-02	1.82E+02	1.11E+02
4.94E+02	0.	4.09E-02	1.98E+02	1.14E+02
5.71E+02	0.	3.27E-02	2.16E+02	1.16E+02
6.60E+02	0.	2.59E-02	2.37E+02	1.19E+02
7.63E+02	0.	2.04E-02	2.61E+02	1.23E+02
8.82E+02	0.	1.59E-02	2.89E+02	1.28E+02
1.02E+03	0.	1.23E-02	3.20E+02	1.33E+02
1.18E+03	0.	9.46E-03	3.56E+02	1.39E+02

4.2 Two-Phase, Horizontal Jet Release

In this problem, liquid ammonia stored under pressure is released producing a two-phase (liquid droplet-vapor mixture), horizontal jet source. The problem is a simulation of the Desert Tortoise 4 experiment conducted by LLNL (Goldwire et al., 1985). Ammonia has a molecular weight that is less than that of air; however, the evaporation of the liquid ammonia droplets cools the ammonia-air mixture producing a cloud with a density greater than that of the ambient air. The release is of finite duration with the SLAB dispersion calculation extending through the steady state plume regime into the transient puff regime.

Input File : INPR2

```
     2
     1
.017031
2045.9
239.57
.81
1170000.
4611.8
603.
2976.01
0.
239.57
107.87
.93
381.
0.
1.
10.
2800.
0.
1.
0.
0.
.003
2.00
4.50
306.2
21.3
0.
.0221
-1.
```

PROBLEM INPUT

IDSPL	=	2
NCALC	=	1
WMS	=	0.017031
CPS	=	2045.90
TBP	=	239.57
CMEDO	=	0.81
DHE	=	1170000.
CPSL	=	4611.80
RHOSL	=	603.00
SPB	=	2976.01
SPC	=	0.00
TS	=	239.57
QS	=	107.87
AS	=	0.93
TSD	=	381.
QTIS	=	0.00
HS	=	1.00
TAV	=	10.00
XFFM	=	2800.00
ZP(1)	=	0.00
ZP(2)	=	1.00
ZP(3)	=	0.00
ZP(4)	=	0.00
Z0	=	0.003000
ZA	=	2.00
UA	=	4.50
TA	=	306.20
RH	=	21.30
STAB	=	0.00
ALA	=	0.0221

RELEASE GAS PROPERTIES

MOLECULAR WEIGHT OF SOURCE GAS (KG)	- WMS	=	1.7031E-02
VAPOR HEAT CAPACITY, CONST. P. (J/KG-K)	- CPS	=	2.0459E+03
TEMPERATURE OF SOURCE GAS (K)	- TS	=	2.3957E+02
DENSITY OF SOURCE GAS (KG/M3)	- RHOS	=	8.6636E-01
BOILING POINT TEMPERATURE	- TBP	=	2.3957E+02
LIQUID MASS FRACTION	- CMEDO	=	8.1000E-01
LIQUID HEAT CAPACITY (J/KG-K)	- CPSL	=	4.6118E+03
HEAT OF VAPORIZATION (J/KG)	- DHE	=	1.1700E+06
LIQUID SOURCE DENSITY (KG/M3)	- RHOSL	=	6.0300E+02
SATURATION PRESSURE CONSTANT	- SPA	=	1.2422E+01
SATURATION PRESSURE CONSTANT (K)	- SPB	=	2.9760E+03
SATURATION PRESSURE CONSTANT (K)	- SPC	=	0.

SPILL CHARACTERISTICS

SPILL TYPE	- IDSPL	=	2
MASS SOURCE RATE (KG/S)	- QS	=	1.0787E+02
CONTINUOUS SOURCE DURATION (S)	- TSD	=	3.8100E+02
CONTINUOUS SOURCE MASS (KG)	- QTCS	=	4.1098E+04
INSTANTANEOUS SOURCE MASS (KG)	- QTIS	=	0.

SOURCE AREA (M2)	- AS	=	9.3000E-01
VERTICAL VAPOR VELOCITY (M/S)	- WS	=	0.
SOURCE HALF WIDTH (M)	- BS	=	4.8218E-01
SOURCE HEIGHT (M)	- HS	=	1.0000E+00
HORIZONTAL VAPOR VELOCITY (M/S)	- US	=	2.5593E+01

FIELD PARAMETERS

CONCENTRATION AVERAGING TIME (S)	- TAV	=	1.0000E+01
MIXING LAYER HEIGHT (M)	- HMX	=	7.2604E+02
MAXIMUM DOWNWIND DISTRACE (M)	- XFFM	=	2.8000E+03
CONCENTRATION MEASUREMENT HEIGHT (M)	- ZP(1)	=	0.
	- ZP(2)	=	1.0000E+00
	- ZP(3)	=	0.
	- ZP(4)	=	0.

AMBIENT METEOROLOGICAL PROPERTIES

MOLECULAR WEIGHT OF AMBIENT AIR (KG)	- WMAE	=	2.8835E-02
HEAT CAPACITY OF AMBIENT AIR AT CONST P. (J/KG-K)	- CPAA	=	1.0119E+03
DENSITY OF AMBIENT AIR (KG/M3)	- RHOA	=	1.1477E+00
AMBIENT MEASUREMENT HEIGHT (M)	- ZA	=	2.0000E+00
AMBIENT ATMOSPHERIC PRESSURE (PA=N/M2=J/M3)	- PA	=	1.0132E+05
AMBIENT WIND SPEED (M/S)	- UA	=	4.5000E+00
AMBIENT TEMPERATURE (K)	- TA	=	3.0620E+02
RELATIVE HUMIDITY (PERCENT)	- RH	=	2.1300E+01
AMBIENT FRICTION VELOCITY (M/S)	- UASTR	=	2.6632E-01
ATMOSPHERIC STABILITY CLASS VALUE	- STAB	=	4.5185E+00
INVERSE MONIN-OBUKHOV LENGTH (1/M)	- ALA	=	2.2100E-02
SURFACE ROUGHNESS HEIGHT (M)	- ZO	=	3.0000E-03

ADDITIONAL PARAMETERS

SUB-STEP MULTIPLIER	- NCALC	=	1
NUMBER OF CALCULATIONAL SUB-STEPS	- NSSM	=	3
ACCELERATION OF GRAVITY (M/S2)	- GRAV	=	9.8066E+00
GAS CONSTANT (J/MOL- K)	- RR	=	8.3143E+00
VON KARMAN CONSTANT	- XK	=	4.1000E-01

1

INSTANTANEOUS SPATIALLY AVERAGED CLOUD PARAMETERS

X	ZC	H	BB	B	BBX	BX	CV	RHO	T	U	UA
1.00E+00	1.00E+00	9.64E-01	4.82E-01	4.34E-01	0.	0.	1.00E+00	4.53E+00	2.40E+02	2.56E+01	3.48E+00
1.02E+00	1.00E+00	9.66E-01	4.83E-01	4.34E-01	1.90E-02	1.90E-02	1.00E+00	4.52E+00	2.40E+02	2.56E+01	3.48E+00
1.04E+00	1.00E+00	9.68E-01	4.84E-01	4.35E-01	4.16E-02	4.16E-02	9.99E-01	4.51E+00	2.39E+02	2.56E+01	3.48E+00
1.07E+00	1.00E+00	9.70E-01	4.85E-01	4.36E-01	6.83E-02	6.83E-02	9.99E-01	4.50E+00	2.39E+02	2.56E+01	3.48E+00
1.10E+00	1.00E+00	9.73E-01	4.86E-01	4.36E-01	1.00E-01	1.00E-01	9.98E-01	4.48E+00	2.39E+02	2.55E+01	3.48E+00
1.13E+00	1.00E+00	9.76E-01	4.88E-01	4.37E-01	1.38E-01	1.38E-01	9.97E-01	4.46E+00	2.39E+02	2.55E+01	3.48E+00
1.18E+00	1.00E+00	9.80E-01	4.90E-01	4.38E-01	1.82E-01	1.82E-01	9.96E-01	4.44E+00	2.39E+02	2.55E+01	3.48E+00
1.23E+00	1.00E+00	9.84E-01	4.92E-01	4.40E-01	2.35E-01	2.35E-01	9.95E-01	4.41E+00	2.39E+02	2.55E+01	3.48E+00
1.29E+00	1.00E+00	9.90E-01	4.95E-01	4.41E-01	2.98E-01	2.98E-01	9.94E-01	4.38E+00	2.39E+02	2.54E+01	3.48E+00
1.36E+00	9.99E-01	9.96E-01	4.98E-01	4.43E-01	3.73E-01	3.73E-01	9.92E-01	4.34E+00	2.39E+02	2.54E+01	3.48E+00
1.45E+00	9.99E-01	1.00E+00	5.02E-01	4.45E-01	4.61E-01	4.61E-01	9.90E-01	4.30E+00	2.39E+02	2.53E+01	3.49E+00
1.55E+00	9.98E-01	1.01E+00	5.06E-01	4.48E-01	5.66E-01	5.66E-01	9.88E-01	4.25E+00	2.38E+02	2.52E+01	3.49E+00
1.68E+00	9.97E-01	1.02E+00	5.12E-01	4.51E-01	6.90E-01	6.90E-01	9.85E-01	4.19E+00	2.38E+02	2.51E+01	3.49E+00
1.82E+00	9.96E-01	1.04E+00	5.19E-01	4.56E-01	8.37E-01	8.37E-01	9.81E-01	4.12E+00	2.38E+02	2.50E+01	3.49E+00
1.99E+00	9.96E-01	1.06E+00	5.28E-01	4.61E-01	1.01E+00	1.01E+00	9.77E-01	4.05E+00	2.37E+02	2.49E+01	3.50E+00
2.19E+00	9.92E-01	1.08E+00	5.38E-01	4.66E-01	1.22E+00	1.22E+00	9.72E-01	3.96E+00	2.37E+02	2.47E+01	3.50E+00
2.43E+00	9.88E-01	1.10E+00	5.50E-01	4.73E-01	1.47E+00	1.47E+00	9.66E-01	3.86E+00	2.37E+02	2.45E+01	3.50E+00
2.72E+00	9.83E-01	1.13E+00	5.66E-01	4.82E-01	1.76E+00	1.76E+00	9.58E-01	3.74E+00	2.36E+02	2.42E+01	3.51E+00
3.06E+00	9.76E-01	1.17E+00	5.85E-01	4.93E-01	2.10E+00	2.10E+00	9.49E-01	3.61E+00	2.35E+02	2.38E+01	3.52E+00
3.46E+00	9.66E-01	1.22E+00	6.08E-01	5.07E-01	2.51E+00	2.51E+00	9.37E-01	3.47E+00	2.34E+02	2.34E+01	3.52E+00
3.94E+00	9.51E-01	1.28E+00	6.38E-01	5.24E-01	3.00E+00	3.00E+00	9.22E-01	3.32E+00	2.34E+02	2.28E+01	3.53E+00
4.50E+00	9.30E-01	1.35E+00	6.74E-01	5.44E-01	3.58E+00	3.58E+00	9.04E-01	3.15E+00	2.33E+02	2.22E+01	3.54E+00
5.17E+00	9.00E-01	1.44E+00	7.20E-01	5.67E-01	4.26E+00	4.26E+00	8.82E-01	2.98E+00	2.31E+02	2.14E+01	3.55E+00
5.97E+00	8.57E-01	1.56E+00	7.79E-01	5.98E-01	5.07E+00	5.07E+00	8.54E-01	2.80E+00	2.30E+02	2.05E+01	3.55E+00
6.91E+00	7.95E-01	1.64E+00	8.70E-01	6.50E-01	6.04E+00	6.04E+00	8.25E-01	2.64E+00	2.29E+02	1.96E+01	3.55E+00
8.03E+00	7.17E-01	1.61E+00	1.04E+00	7.53E-01	7.18E+00	7.18E+00	7.95E-01	2.50E+00	2.27E+02	1.85E+01	3.54E+00
9.35E+00	6.32E-01	1.59E+00	1.27E+00	8.93E-01	8.54E+00	8.54E+00	7.60E-01	2.36E+00	2.26E+02	1.74E+01	3.53E+00
1.09E+01	5.46E-01	1.57E+00	1.58E+00	1.08E+00	1.01E+01	1.01E+01	7.20E-01	2.23E+00	2.25E+02	1.61E+01	3.52E+00
1.28E+01	4.65E-01	1.56E+00	2.00E+00	1.31E+00	1.21E+01	1.20E+01	6.75E-01	2.11E+00	2.23E+02	1.48E+01	3.52E+00
1.50E+01	3.91E-01	1.58E+00	2.55E+00	1.61E+00	1.43E+01	1.43E+01	6.25E-01	2.01E+00	2.22E+02	1.35E+01	3.52E+00
1.76E+01	3.26E-01	1.61E+00	3.25E+00	1.99E+00	1.70E+01	1.70E+01	5.72E-01	1.91E+00	2.20E+02	1.22E+01	3.54E+00
2.07E+01	2.70E-01	1.67E+00	4.16E+00	2.46E+00	2.02E+01	2.02E+01	5.17E-01	1.83E+00	2.19E+02	1.10E+01	3.57E+00
2.44E+01	2.22E-01	1.73E+00	5.33E+00	3.04E+00	2.39E+01	2.39E+01	4.64E-01	1.76E+00	2.18E+02	9.83E+00	3.60E+00
2.88E+01	1.82E-01	1.80E+00	6.81E+00	3.77E+00	2.84E+01	2.84E+01	4.12E-01	1.71E+00	2.16E+02	8.82E+00	3.63E+00
3.40E+01	1.49E-01	1.86E+00	8.68E+00	4.68E+00	3.37E+01	3.37E+01	3.64E-01	1.66E+00	2.15E+02	7.94E+00	3.65E+00
4.02E+01	1.21E-01	1.92E+00	1.11E+01	5.80E+00	4.00E+01	4.00E+01	3.20E-01	1.62E+00	2.14E+02	7.19E+00	3.68E+00
4.75E+01	9.82E-02	1.98E+00	1.40E+01	7.20E+00	4.75E+01	4.75E+01	2.80E-01	1.59E+00	2.14E+02	6.54E+00	3.70E+00
5.62E+01	7.96E-02	2.03E+00	1.78E+01	8.94E+00	5.64E+01	5.63E+01	2.43E-01	1.57E+00	2.13E+02	5.99E+00	3.72E+00
6.64E+01	6.45E-02	2.08E+00	2.24E+01	1.11E+01	6.69E+01	6.69E+01	2.09E-01	1.54E+00	2.12E+02	5.53E+00	3.74E+00
7.86E+01	5.24E-02	2.21E+00	2.82E+01	1.37E+01	7.93E+01	7.93E+01	1.78E-01	1.47E+00	2.24E+02	5.18E+00	3.79E+00
9.31E+01	4.29E-02	2.41E+00	3.51E+01	1.68E+01	9.41E+01	9.41E+01	1.50E-01	1.38E+00	2.41E+02	4.92E+00	3.86E+00
1.10E+02	3.57E-02	2.63E+00	4.30E+01	2.02E+01	1.12E+02	1.12E+02	1.23E-01	1.32E+00	2.55E+02	4.72E+00	3.93E+00
1.31E+02	3.02E-02	2.89E+00	5.17E+01	2.39E+01	1.32E+02	1.32E+02	1.00E-01	1.28E+00	2.66E+02	4.58E+00	4.00E+00
1.55E+02	2.59E-02	3.18E+00	6.11E+01	2.79E+01	1.57E+02	1.57E+02	8.08E-02	1.25E+00	2.73E+02	4.50E+00	4.08E+00
1.83E+02	2.26E-02	3.51E+00	7.12E+01	3.20E+01	1.86E+02	1.86E+02	6.46E-02	1.23E+00	2.78E+02	4.46E+00	4.16E+00
2.17E+02	1.99E-02	3.90E+00	8.20E+01	3.64E+01	2.21E+02	2.21E+02	5.15E-02	1.22E+00	2.82E+02	4.45E+00	4.25E+00
2.58E+02	1.77E-02	4.38E+00	9.36E+01	4.09E+01	2.62E+02	2.62E+02	4.06E-02	1.20E+00	2.88E+02	4.49E+00	4.34E+00
3.05E+02	1.59E-02	4.99E+00	1.06E+02	4.55E+01	3.11E+02	3.11E+02	3.17E-02	1.19E+00	2.92E+02	4.55E+00	4.45E+00
3.62E+02	1.44E-02	5.74E+00	1.18E+02	5.02E+01	3.69E+02	3.69E+02	2.44E-02	1.18E+00	2.96E+02	4.63E+00	4.57E+00
4.29E+02	1.32E-02	6.66E+00	1.31E+02	5.48E+01	4.38E+02	4.37E+02	1.87E-02	1.17E+00	2.99E+02	4.74E+00	4.70E+00
5.09E+02	1.22E-02	7.77E+00	1.45E+02	5.93E+01	5.19E+02	5.19E+02	1.43E-02	1.16E+00	3.01E+02	4.85E+00	4.83E+00
6.03E+02	1.13E-02	9.12E+00	1.58E+02	6.38E+01	6.16E+02	6.16E+02	1.09E-02	1.16E+00	3.02E+02	4.98E+00	4.97E+00
7.16E+02	1.06E-02	1.07E+01	1.73E+02	6.83E+01	7.30E+02	7.30E+02	8.32E-03	1.16E+00	3.03E+02	5.11E+00	5.11E+00
8.49E+02	9.93E-03	1.26E+01	1.88E+02	7.27E+01	8.66E+02	8.66E+02	6.35E-03	1.15E+00	3.04E+02	5.25E+00	5.25E+00

1.01E+03	9.35E-03	1.49E+01	2.04E+02	7.72E+01	1.03E+03	1.03E+03	4.86E-03	1.15E+00	3.05E+02	5.39E+00	5.39E+00
1.20E+03	8.81E-03	1.79E+01	2.20E+02	8.18E+01	1.06E+03	1.03E+03	3.61E-03	1.15E+00	3.05E+02	5.56E+00	5.56E+00
1.43E+03	8.32E-03	2.15E+01	2.39E+02	8.64E+01	1.10E+03	1.03E+03	2.67E-03	1.15E+00	3.05E+02	5.72E+00	5.72E+00
1.71E+03	7.87E-03	2.58E+01	2.59E+02	9.11E+01	1.15E+03	1.03E+03	1.97E-03	1.15E+00	3.06E+02	5.89E+00	5.89E+00
2.06E+03	7.45E-03	3.09E+01	2.80E+02	9.60E+01	1.21E+03	1.04E+03	1.45E-03	1.15E+00	3.06E+02	6.05E+00	6.05E+00
2.48E+03	7.07E-03	3.69E+01	3.04E+02	1.01E+02	1.28E+03	1.04E+03	1.06E-03	1.15E+00	3.06E+02	6.21E+00	6.21E+00
2.99E+03	6.71E-03	4.40E+01	3.30E+02	1.06E+02	1.36E+03	1.04E+03	7.67E-04	1.15E+00	3.06E+02	6.37E+00	6.37E+00

1

X	CM	CMV	CMDA	CMW	CMWV	WC	VG	UG	W	V	VX
1.00E+00	1.00E+00	1.90E-01	0.	0.	0.	0.	0.	0.	6.15E-01	4.96E-01	0.
1.02E+00	9.99E-01	1.90E-01	6.60E-04	4.74E-06	4.74E-06	-5.32E-03	0.	0.	1.04E+00	4.97E-01	4.82E-01
1.04E+00	9.99E-01	1.90E-01	1.45E-03	1.04E-05	1.04E-05	-1.16E-02	0.	0.	1.04E+00	4.98E-01	4.82E-01
1.07E+00	9.98E-01	1.90E-01	2.40E-03	1.72E-05	1.72E-05	-1.91E-02	0.	0.	1.05E+00	4.99E-01	4.82E-01
1.10E+00	9.96E-01	1.90E-01	3.52E-03	2.53E-05	2.53E-05	-2.79E-02	0.	0.	1.05E+00	5.01E-01	4.82E-01
1.13E+00	9.95E-01	1.90E-01	4.87E-03	3.49E-05	3.49E-05	-3.84E-02	0.	0.	1.06E+00	5.02E-01	4.82E-01
1.18E+00	9.93E-01	1.90E-01	6.46E-03	4.64E-05	4.64E-05	-5.08E-02	0.	0.	1.07E+00	5.04E-01	4.82E-01
1.23E+00	9.92E-01	1.91E-01	8.37E-03	6.01E-05	6.01E-05	-6.55E-02	0.	0.	1.08E+00	5.06E-01	4.82E-01
1.29E+00	9.89E-01	1.91E-01	1.07E-02	7.64E-05	7.02E-05	-8.28E-02	0.	0.	1.09E+00	5.09E-01	4.82E-01
1.36E+00	9.87E-01	1.91E-01	1.34E-02	9.60E-05	6.98E-05	-1.03E-01	0.	0.	1.10E+00	5.12E-01	4.82E-01
1.45E+00	9.83E-01	1.91E-01	1.67E-02	1.20E-04	6.93E-05	-1.27E-01	0.	0.	1.11E+00	5.16E-01	4.82E-01
1.55E+00	9.79E-01	1.92E-01	2.06E-02	1.48E-04	6.87E-05	-1.56E-01	0.	0.	1.13E+00	5.20E-01	4.82E-01
1.68E+00	9.74E-01	1.92E-01	2.53E-02	1.82E-04	6.81E-05	-1.90E-01	0.	0.	1.16E+00	5.24E-01	4.82E-01
1.82E+00	9.69E-01	1.92E-01	3.10E-02	2.23E-04	6.73E-05	-2.29E-01	0.	0.	1.17E+00	5.30E-01	4.82E-01
1.99E+00	9.62E-01	1.93E-01	3.79E-02	2.72E-04	6.63E-05	-2.76E-01	0.	0.	1.20E+00	5.36E-01	4.83E-01
2.19E+00	9.53E-01	1.93E-01	4.62E-02	3.32E-04	6.52E-05	-3.30E-01	0.	0.	1.23E+00	5.43E-01	4.83E-01
2.43E+00	9.43E-01	1.93E-01	5.63E-02	4.04E-04	6.39E-05	-3.94E-01	0.	0.	1.26E+00	5.51E-01	4.83E-01
2.72E+00	9.31E-01	1.94E-01	6.86E-02	4.92E-04	6.23E-05	-4.69E-01	0.	0.	1.30E+00	5.60E-01	4.83E-01
3.06E+00	9.16E-01	1.94E-01	8.35E-02	5.99E-04	6.06E-05	-5.55E-01	0.	0.	1.35E+00	5.69E-01	4.83E-01
3.46E+00	8.98E-01	1.94E-01	1.02E-01	7.30E-04	5.84E-05	-6.56E-01	0.	0.	1.40E+00	5.79E-01	4.82E-01
3.94E+00	8.75E-01	1.94E-01	1.24E-01	8.89E-04	5.59E-05	-7.71E-01	0.	0.	1.45E+00	5.90E-01	4.82E-01
4.50E+00	8.48E-01	1.94E-01	1.51E-01	1.08E-03	5.31E-05	-9.03E-01	0.	0.	1.51E+00	5.99E-01	4.82E-01
5.17E+00	8.15E-01	1.93E-01	1.83E-01	1.32E-03	4.99E-05	-1.05E+00	0.	0.	1.57E+00	6.08E-01	4.81E-01
5.97E+00	7.76E-01	1.91E-01	2.22E-01	1.59E-03	4.64E-05	-1.22E+00	0.	0.	1.63E+00	6.12E-01	4.80E-01
6.91E+00	7.36E-01	1.89E-01	2.62E-01	1.88E-03	4.31E-05	-1.37E+00	1.50E+00	0.	9.66E-01	6.11E-01	4.78E-01
8.03E+00	6.96E-01	1.87E-01	3.02E-01	2.16E-03	4.01E-05	-1.25E+00	1.82E+00	0.	9.30E-01	6.05E-01	4.75E-01
9.35E+00	6.52E-01	1.85E-01	3.46E-01	2.48E-03	3.71E-05	-1.04E+00	2.09E+00	0.	8.88E-01	5.92E-01	4.72E-01
1.09E+01	6.03E-01	1.81E-01	3.94E-01	2.83E-03	3.39E-05	-7.93E-01	2.30E+00	0.	8.33E-01	5.72E-01	4.69E-01
1.28E+01	5.50E-01	1.77E-01	4.46E-01	3.20E-03	3.08E-05	-5.69E-01	2.45E+00	0.	7.63E-01	5.43E-01	4.65E-01
1.50E+01	4.96E-01	1.72E-01	5.01E-01	3.59E-03	2.78E-05	-3.90E-01	2.54E+00	0.	6.80E-01	5.06E-01	4.63E-01
1.76E+01	4.41E-01	1.66E-01	5.55E-01	3.98E-03	2.49E-05	-2.59E-01	2.58E+00	0.	5.88E-01	4.63E-01	4.61E-01
2.07E+01	3.88E-01	1.60E-01	6.08E-01	4.36E-03	2.23E-05	-1.68E-01	2.58E+00	0.	4.95E-01	4.15E-01	4.59E-01
2.44E+01	3.38E-01	1.55E-01	6.57E-01	4.72E-03	2.01E-05	-1.07E-01	2.56E+00	0.	4.08E-01	3.66E-01	4.58E-01
2.88E+01	2.93E-01	1.49E-01	7.02E-01	5.04E-03	1.82E-05	-6.79E-02	2.53E+00	0.	3.31E-01	3.19E-01	4.58E-01
3.40E+01	2.53E-01	1.44E-01	7.42E-01	5.32E-03	1.66E-05	-4.29E-02	2.50E+00	0.	2.67E-01	2.75E-01	4.58E-01
4.02E+01	2.17E-01	1.39E-01	7.77E-01	5.57E-03	1.52E-05	-2.70E-02	2.46E+00	0.	2.15E-01	2.36E-01	4.58E-01
4.75E+01	1.86E-01	1.35E-01	8.08E-01	5.80E-03	1.41E-05	-1.70E-02	2.43E+00	0.	1.75E-01	2.02E-01	4.58E-01
5.62E+01	1.59E-01	1.31E-01	8.35E-01	5.99E-03	1.32E-05	-1.07E-02	2.38E+00	0.	1.44E-01	1.73E-01	4.58E-01
6.64E+01	1.35E-01	1.28E-01	8.59E-01	6.16E-03	1.24E-05	-6.69E-03	2.33E+00	0.	1.20E-01	1.49E-01	4.59E-01
7.86E+01	1.14E-01	1.14E-01	8.80E-01	6.31E-03	4.83E-05	-4.18E-03	2.25E+00	0.	1.05E-01	1.33E-01	4.61E-01
9.31E+01	9.41E-02	9.41E-02	8.99E-01	6.45E-03	2.74E-04	-2.58E-03	2.11E+00	0.	9.48E-02	1.20E-01	4.64E-01
1.10E+02	7.67E-02	7.67E-02	9.17E-01	6.58E-03	9.56E-04	-1.59E-03	1.92E+00	0.	8.65E-02	1.09E-01	4.68E-01
1.31E+02	6.18E-02	6.18E-02	9.32E-01	6.68E-03	2.22E-03	-1.00E-03	1.71E+00	0.	7.94E-02	1.01E-01	4.72E-01
1.55E+02	4.93E-02	4.93E-02	9.44E-01	6.77E-03	3.86E-03	-6.43E-04	1.52E+00	0.	7.31E-02	9.53E-02	4.77E-01
1.83E+02	3.92E-02	3.92E-02	9.54E-01	6.84E-03	5.55E-03	-4.26E-04	1.35E+00	0.	6.77E-02	9.13E-02	4.82E-01
2.17E+02	3.11E-02	3.11E-02	9.62E-01	6.90E-03	6.90E-03	-2.92E-04	1.20E+00	0.	6.35E-02	8.85E-02	4.87E-01
2.58E+02	2.44E-02	2.44E-02	9.69E-01	6.95E-03	6.95E-03	-2.03E-04	1.07E+00	0.	6.32E-02	8.65E-02	4.93E-01
3.05E+02	1.89E-02	1.89E-02	9.74E-01	6.99E-03	6.99E-03	-1.42E-04	9.42E-01	0.	6.33E-02	8.51E-02	4.99E-01
3.62E+02	1.46E-02	1.46E-02	9.78E-01	7.02E-03	7.02E-03	-1.00E-04	8.21E-01	0.	6.37E-02	8.41E-02	5.06E-01
4.29E+02	1.12E-02	1.12E-02	9.82E-01	7.04E-03	7.04E-03	-7.18E-05	7.14E-01	0.	6.42E-02	8.33E-02	5.14E-01
5.09E+02	8.50E-03	8.50E-03	9.84E-01	7.06E-03	7.06E-03	-5.23E-05	6.21E-01	0.	6.49E-02	8.26E-02	5.21E-01
6.03E+02	6.47E-03	6.47E-03	9.86E-01	7.08E-03	7.08E-03	-3.87E-05	5.42E-01	0.	6.55E-02	8.20E-02	5.29E-01
7.16E+02	4.93E-03	4.93E-03	9.88E-01	7.09E-03	7.09E-03	-2.91E-05	4.76E-01	0.	6.60E-02	8.13E-02	5.36E-01
8.49E+02	3.76E-03	3.76E-03	9.89E-01	7.10E-03	7.10E-03	-2.22E-05	4.21E-01	0.	6.64E-02	8.07E-02	5.43E-01
1.01E+03	2.87E-03	2.87E-03	9.90E-01	7.10E-03	7.10E-03	-1.72E-05	3.75E-01	7.43E-02	6.67E-02	7.99E-02	5.50E-01
1.20E+03	2.13E-03	2.13E-03	9.91E-01	7.11E-03	7.11E-03	-1.36E-05	3.27E-01	6.53E-02	6.66E-02	7.93E-02	5.36E-01
1.43E+03	1.58E-03	1.58E-03	9.91E-01	7.11E-03	7.11E-03	-1.05E-05	2.88E-01	5.83E-02	6.65E-02	7.86E-02	5.40E-01

1.71E+03	1.16E-03	1.16E-03	9.92E-01	7.11E-03	7.11E-03	-8.15E-06	2.56E-01	5.27E-02	6.63E-02	7.76E-02	5.44E-01
2.06E+03	8.54E-04	8.54E-04	9.92E-01	7.12E-03	7.12E-03	-6.35E-06	2.28E-01	4.79E-02	6.60E-02	7.64E-02	5.48E-01
2.48E+03	6.24E-04	6.24E-04	9.92E-01	7.12E-03	7.12E-03	-4.97E-06	2.03E-01	4.38E-02	6.55E-02	7.50E-02	5.50E-01
2.99E+03	4.53E-04	4.53E-04	9.92E-01	7.12E-03	7.12E-03	-3.88E-06	1.81E-01	4.00E-02	6.48E-02	7.34E-02	5.51E-01

1

TIME AVERAGED (TAV = 10. S) VOLUME CONCENTRATION: CONCENTRATION CONTOUR PARAMETERS

```
C(X,Y,Z,T) = CC(X) * (ERF(XA)-ERF(XB)) * (ERF(YA)-ERF(YB)) * (EXP(-ZA*ZA)+EXP(-ZB*ZB))

   C(X,Y,Z,T) = CONCENTRATION (VOLUME FRACTION) AT (X,Y,Z,T)
            X = DOWNWIND DISTANCE (M)
            Y = CROSSWIND HORIZONTAL DISTANCE (M)
            Z = HEIGHT (M)
            T = TIME (S)

          ERF = ERROR FUNCTON
           XA = (X-XC+BX)/(SR2*BETAX)
           XB = (X-XC-BX)/(SR2*BETAX)
           YA = (Y+B)/(SR2*BETAC)
           YB = (Y-B)/(SR2*BETAC)
          EXP = EXPONENTIAL FUNCTION
           ZA = (Z-ZC)/(SR2*SIG)
           ZB = (Z+ZC)/(SR2*SIG)
          SR2 = SQRT(2.0)
```

X	CC(X)	B(X)	BETAC(X)	ZC(X)	SIG(X)
1.00E+00	0.	4.34E-01	1.21E-01	1.00E+00	2.78E-01
1.02E+00	3.84E-01	4.34E-01	1.22E-01	1.00E+00	2.79E-01
1.04E+00	3.84E-01	4.35E-01	1.22E-01	1.00E+00	2.79E-01
1.07E+00	3.84E-01	4.36E-01	1.23E-01	1.00E+00	2.80E-01
1.10E+00	3.84E-01	4.36E-01	1.24E-01	1.00E+00	2.81E-01
1.13E+00	3.84E-01	4.37E-01	1.25E-01	1.00E+00	2.82E-01
1.18E+00	3.84E-01	4.38E-01	1.26E-01	1.00E+00	2.83E-01
1.23E+00	3.85E-01	4.40E-01	1.27E-01	1.00E+00	2.84E-01
1.29E+00	3.85E-01	4.41E-01	1.29E-01	1.00E+00	2.86E-01
1.36E+00	3.85E-01	4.43E-01	1.31E-01	9.99E-01	2.88E-01
1.45E+00	3.85E-01	4.45E-01	1.33E-01	9.99E-01	2.90E-01
1.55E+00	3.86E-01	4.48E-01	1.36E-01	9.98E-01	2.93E-01
1.68E+00	3.86E-01	4.51E-01	1.40E-01	9.97E-01	2.96E-01
1.82E+00	3.86E-01	4.56E-01	1.44E-01	9.96E-01	3.00E-01
1.99E+00	3.87E-01	4.61E-01	1.49E-01	9.95E-01	3.05E-01
2.19E+00	3.87E-01	4.66E-01	1.55E-01	9.92E-01	3.11E-01
2.43E+00	3.88E-01	4.73E-01	1.62E-01	9.88E-01	3.18E-01
2.72E+00	3.89E-01	4.82E-01	1.71E-01	9.83E-01	3.27E-01
3.06E+00	3.89E-01	4.93E-01	1.81E-01	9.76E-01	3.38E-01
3.46E+00	3.88E-01	5.07E-01	1.94E-01	9.66E-01	3.51E-01
3.94E+00	3.88E-01	5.24E-01	2.10E-01	9.51E-01	3.68E-01
4.50E+00	3.87E-01	5.44E-01	2.30E-01	9.30E-01	3.89E-01
5.17E+00	3.87E-01	5.67E-01	2.56E-01	9.00E-01	4.16E-01
5.97E+00	3.85E-01	5.98E-01	2.88E-01	8.57E-01	4.50E-01
6.91E+00	3.71E-01	6.50E-01	3.34E-01	7.95E-01	4.86E-01
8.03E+00	3.41E-01	7.53E-01	4.13E-01	7.17E-01	5.18E-01
9.35E+00	3.11E-01	8.93E-01	5.23E-01	6.32E-01	5.52E-01
1.09E+01	2.81E-01	1.08E+00	6.72E-01	5.46E-01	5.89E-01
1.28E+01	2.53E-01	1.31E+00	8.72E-01	4.65E-01	6.33E-01
1.50E+01	2.27E-01	1.61E+00	1.14E+00	3.91E-01	6.85E-01
1.76E+01	2.03E-01	1.99E+00	1.49E+00	3.26E-01	7.44E-01
2.07E+01	1.81E-01	2.46E+00	1.94E+00	2.70E-01	8.07E-01
2.44E+01	1.61E-01	3.04E+00	2.52E+00	2.22E-01	8.71E-01
2.88E+01	1.43E-01	3.77E+00	3.27E+00	1.82E-01	9.33E-01
3.40E+01	1.27E-01	4.68E+00	4.22E+00	1.49E-01	9.90E-01
4.02E+01	1.12E-01	5.80E+00	5.43E+00	1.21E-01	1.04E+00
4.75E+01	9.90E-02	7.20E+00	6.96E+00	9.82E-02	1.09E+00

T	XC(T)	BX(T)	BETAX(T)
0.	1.00E+00	0.	0.
1.38E-03	1.02E+00	1.90E-02	1.55E-04
3.10E-03	1.04E+00	4.16E-02	3.39E-04
5.15E-03	1.07E+00	6.83E-02	5.58E-04
7.58E-03	1.10E+00	1.00E-01	8.17E-04
1.05E-02	1.13E+00	1.38E-01	1.12E-03
1.39E-02	1.18E+00	1.82E-01	1.49E-03
1.80E-02	1.23E+00	2.35E-01	1.92E-03
2.28E-02	1.29E+00	2.98E-01	2.43E-03
2.85E-02	1.36E+00	3.73E-01	3.04E-03
3.54E-02	1.45E+00	4.61E-01	3.76E-03
4.35E-02	1.55E+00	5.66E-01	4.62E-03
5.31E-02	1.68E+00	6.90E-01	5.63E-03
6.46E-02	1.82E+00	8.37E-01	6.84E-03
7.83E-02	1.99E+00	1.01E+00	8.26E-03
9.47E-02	2.19E+00	1.22E+00	9.96E-03
1.14E-01	2.43E+00	1.47E+00	1.20E-02
1.38E-01	2.72E+00	1.76E+00	1.43E-02
1.66E-01	3.06E+00	2.10E+00	1.72E-02
2.00E-01	3.46E+00	2.51E+00	2.05E-02
2.41E-01	3.94E+00	3.00E+00	2.45E-02
2.91E-01	4.50E+00	3.58E+00	2.92E-02
3.53E-01	5.17E+00	4.26E+00	3.48E-02
4.29E-01	5.97E+00	5.07E+00	4.14E-02
5.23E-01	6.91E+00	6.04E+00	4.93E-02
6.41E-01	8.03E+00	7.18E+00	5.86E-02
7.89E-01	9.35E+00	8.54E+00	6.97E-02
9.77E-01	1.09E+01	1.01E+01	8.28E-02
1.22E+00	1.28E+01	1.20E+01	9.84E-02
1.53E+00	1.50E+01	1.43E+01	1.17E-01
1.94E+00	1.76E+01	1.70E+01	1.39E-01
2.48E+00	2.07E+01	2.02E+01	1.65E-01
3.19E+00	2.44E+01	2.39E+01	1.96E-01
4.14E+00	2.88E+01	2.84E+01	2.32E-01
5.38E+00	3.40E+01	3.37E+01	2.76E-01
7.02E+00	4.02E+01	4.00E+01	3.27E-01
9.15E+00	4.75E+01	4.75E+01	3.88E-01

5.62E+01	8.68E-02	8.94E+00	8.88E+00	7.96E-02	1.13E+00
6.64E+01	7.56E-02	1.11E+01	1.13E+01	6.45E-02	1.17E+00
7.86E+01	6.51E-02	1.37E+01	1.42E+01	5.24E-02	1.25E+00
9.31E+01	5.51E-02	1.68E+01	1.78E+01	4.29E-02	1.36E+00
1.10E+02	4.59E-02	2.02E+01	2.19E+01	3.57E-02	1.60E+00
1.31E+02	3.78E-02	2.39E+01	2.64E+01	3.02E-02	1.65E+00
1.65E+02	3.08E-02	2.79E+01	3.14E+01	2.59E-02	1.82E+00
1.83E+02	2.50E-02	3.20E+01	3.67E+01	2.26E-02	2.02E+00
2.17E+02	2.02E-02	3.64E+01	4.25E+01	1.99E-02	2.24E+00
2.58E+02	1.61E-02	4.09E+01	4.86E+01	1.77E-02	2.52E+00
3.05E+02	1.28E-02	4.55E+01	5.51E+01	1.69E-02	2.87E+00
3.62E+02	9.99E-03	5.02E+01	6.19E+01	1.44E-02	3.31E+00
4.29E+02	7.79E-03	5.48E+01	6.90E+01	1.32E-02	3.84E+00
5.09E+02	6.05E-03	5.93E+01	7.63E+01	1.22E-02	4.48E+00
6.03E+02	4.69E-03	6.38E+01	8.39E+01	1.13E-02	5.26E+00
7.16E+02	3.65E-03	6.83E+01	9.18E+01	1.06E-02	6.18E+00
8.49E+02	2.84E-03	7.27E+01	1.00E+02	9.93E-03	7.28E+00
1.01E+03	2.22E-03	7.72E+01	1.09E+02	9.35E-03	8.57E+00
1.20E+03	1.74E-03	8.18E+01	1.19E+02	8.81E-03	1.03E+01
1.43E+03	1.37E-03	8.64E+01	1.29E+02	8.32E-03	1.24E+01
1.71E+03	1.08E-03	9.11E+01	1.40E+02	7.87E-03	1.49E+01
2.06E+03	8.55E-04	9.60E+01	1.53E+02	7.45E-03	1.78E+01
2.48E+03	6.79E-04	1.01E+02	1.67E+02	7.07E-03	2.13E+01
2.99E+03	5.42E-04	1.06E+02	1.82E+02	6.71E-03	2.54E+01

1.19E+01	5.62E+01	5.63E+01	4.60E-01
1.55E+01	6.64E+01	6.69E+01	5.46E-01
2.01E+01	7.86E+01	7.93E+01	6.48E-01
2.58E+01	9.31E+01	9.41E+01	7.68E-01
3.29E+01	1.10E+02	1.12E+02	9.11E-01
4.17E+01	1.31E+02	1.32E+02	1.08E+00
5.23E+01	1.65E+02	1.57E+02	1.28E+00
6.61E+01	1.83E+02	1.86E+02	1.52E+00
8.04E+01	2.17E+02	2.21E+02	1.80E+00
9.84E+01	2.58E+02	2.62E+02	2.14E+00
1.20E+02	3.05E+02	3.11E+02	2.54E+00
1.44E+02	3.62E+02	3.69E+02	3.01E+00
1.73E+02	4.29E+02	4.37E+02	3.57E+00
2.06E+02	5.09E+02	5.19E+02	4.24E+00
2.45E+02	6.03E+02	6.16E+02	5.03E+00
2.89E+02	7.16E+02	7.30E+02	5.96E+00
3.40E+02	8.49E+02	8.66E+02	7.07E+00
4.00E+02	1.01E+03	1.03E+03	8.39E+00
4.16E+02	1.20E+03	1.03E+03	1.50E+02
4.57E+02	1.43E+03	1.03E+03	2.24E+02
5.06E+02	1.71E+03	1.03E+03	2.91E+02
5.64E+02	2.06E+03	1.04E+03	3.68E+02
6.32E+02	2.48E+03	1.04E+03	4.28E+02
7.14E+02	2.99E+03	1.04E+03	5.03E+02

1

TIME AVERAGED (TAV = 10. S) VOLUME CONCENTRATION: CONCENTRATION IN THE Z = 0.00 PLANE.

DOWNWIND DISTANCE X (M)	TIME OF MAX CONC (S)	CLOUD DURATION (S)	EFFECTIVE HALF WIDTH BBC (M)	AVERAGE CONCENTRATION (VOLUME FRACTION) AT (X,Y,Z) Y/BBC= 0.0	Y/BBC= 0.5	Y/BBC= 1.0	Y/BBC= 1.5	Y/BBC= 2.0	Y/BBC= 2.5
1.00E+00	1.91E+02	3.81E+02	4.82E-01	4.84E-03	4.57E-03	1.67E-03	4.15E-05	3.00E-08	4.96E-13
1.02E+00	1.91E+02	3.81E+02	4.83E-01	4.95E-03	4.67E-03	1.71E-03	4.28E-05	3.17E-08	5.45E-13
1.04E+00	1.91E+02	3.81E+02	4.84E-01	5.08E-03	4.79E-03	1.75E-03	4.44E-05	3.39E-08	6.17E-13
1.07E+00	1.91E+02	3.81E+02	4.85E-01	5.24E-03	4.93E-03	1.80E-03	4.64E-05	3.68E-08	7.13E-13
1.10E+00	1.91E+02	3.81E+02	4.86E-01	5.43E-03	5.11E-03	1.87E-03	4.88E-05	4.06E-08	8.46E-13
1.13E+00	1.91E+02	3.81E+02	4.88E-01	5.66E-03	5.32E-03	1.94E-03	5.19E-05	4.54E-08	1.03E-12
1.18E+00	1.91E+02	3.81E+02	4.90E-01	5.95E-03	5.59E-03	2.04E-03	5.57E-05	5.19E-08	1.31E-12
1.23E+00	1.91E+02	3.81E+02	4.92E-01	6.32E-03	5.92E-03	2.16E-03	6.06E-05	6.07E-08	1.72E-12
1.29E+00	1.91E+02	3.81E+02	4.95E-01	6.78E-03	6.34E-03	2.30E-03	6.70E-05	7.28E-08	2.36E-12
1.36E+00	1.91E+02	3.81E+02	4.98E-01	7.37E-03	6.87E-03	2.50E-03	7.53E-05	9.01E-08	3.42E-12
1.45E+00	1.91E+02	3.81E+02	5.02E-01	8.14E-03	7.56E-03	2.74E-03	8.64E-05	1.15E-07	5.25E-12
1.55E+00	1.91E+02	3.81E+02	5.06E-01	9.15E-03	8.46E-03	3.06E-03	1.01E-04	1.54E-07	8.60E-12
1.68E+00	1.91E+02	3.81E+02	5.12E-01	1.05E-02	9.66E-03	3.49E-03	1.23E-04	2.16E-07	1.55E-11
1.82E+00	1.91E+02	3.81E+02	5.19E-01	1.24E-02	1.14E-02	4.09E-03	1.53E-04	3.14E-07	2.91E-11
1.99E+00	1.91E+02	3.81E+02	5.28E-01	1.51E-02	1.37E-02	4.93E-03	1.97E-04	4.83E-07	5.94E-11
2.19E+00	1.91E+02	3.81E+02	5.38E-01	1.90E-02	1.71E-02	6.12E-03	2.65E-04	7.86E-07	1.33E-10
2.43E+00	1.91E+02	3.81E+02	5.50E-01	2.47E-02	2.21E-02	7.87E-03	3.71E-04	1.36E-06	3.28E-10
2.72E+00	1.91E+02	3.81E+02	5.66E-01	3.35E-02	2.95E-02	1.05E-02	5.41E-04	2.48E-06	8.58E-10
3.06E+00	1.91E+02	3.81E+02	5.85E-01	4.75E-02	4.14E-02	1.47E-02	8.19E-04	4.58E-06	2.19E-09
3.46E+00	1.91E+02	3.81E+02	6.08E-01	7.05E-02	6.07E-02	2.14E-02	1.30E-03	9.05E-06	6.16E-09
3.94E+00	1.91E+02	3.81E+02	6.38E-01	1.09E-01	9.25E-02	3.25E-02	2.17E-03	1.90E-05	1.89E-08
4.50E+00	1.91E+02	3.81E+02	6.74E-01	1.76E-01	1.46E-01	5.11E-02	3.77E-03	4.21E-05	6.26E-08
5.17E+00	1.91E+02	3.81E+02	7.20E-01	2.90E-01	2.36E-01	8.20E-02	6.72E-03	9.65E-05	2.16E-07
5.97E+00	1.91E+02	3.81E+02	7.79E-01	4.82E-01	3.83E-01	1.33E-01	1.20E-02	2.17E-04	7.09E-07
6.91E+00	1.92E+02	3.81E+02	8.70E-01	7.39E-01	5.76E-01	1.99E-01	1.94E-02	4.30E-04	1.95E-06
8.03E+00	1.92E+02	3.81E+02	1.04E+00	9.76E-01	7.47E-01	2.56E-01	2.69E-02	7.05E-04	4.23E-06
9.35E+00	1.92E+02	3.81E+02	1.27E+00	1.00E+00	8.86E-01	3.02E-01	3.37E-02	1.03E-03	7.89E-06
1.09E+01	1.92E+02	3.81E+02	1.58E+00	1.00E+00	9.67E-01	3.28E-01	3.86E-02	1.34E-03	1.27E-05
1.28E+01	1.93E+02	3.81E+02	2.00E+00	1.00E+00	9.83E-01	3.32E-01	4.08E-02	1.58E-03	1.80E-05
1.50E+01	1.93E+02	3.81E+02	2.55E+00	1.00E+00	9.42E-01	3.17E-01	4.04E-02	1.71E-03	2.27E-05
1.76E+01	1.94E+02	3.81E+02	3.25E+00	1.00E+00	8.66E-01	2.90E-01	3.81E-02	1.75E-03	2.63E-05
2.07E+01	1.94E+02	3.81E+02	4.16E+00	1.00E+00	7.75E-01	2.59E-01	3.48E-02	1.70E-03	2.84E-05
2.44E+01	1.95E+02	3.81E+02	5.33E+00	9.62E-01	6.83E-01	2.27E-01	3.11E-02	1.60E-03	2.92E-05
2.88E+01	1.96E+02	3.81E+02	6.81E+00	8.43E-01	5.96E-01	1.98E-01	2.75E-02	1.47E-03	2.89E-05
3.40E+01	1.97E+02	3.81E+02	8.68E+00	7.35E-01	5.17E-01	1.71E-01	2.41E-02	1.34E-03	2.77E-05
4.02E+01	1.98E+02	3.81E+02	1.11E+01	6.38E-01	4.48E-01	1.48E-01	2.11E-02	1.20E-03	2.60E-05
4.75E+01	1.99E+02	3.81E+02	1.40E+01	5.52E-01	3.87E-01	1.28E-01	1.83E-02	1.06E-03	2.40E-05
5.62E+01	2.01E+02	3.81E+02	1.78E+01	4.75E-01	3.32E-01	1.10E-01	1.58E-02	9.35E-04	2.18E-05
6.64E+01	2.03E+02	3.81E+02	2.24E+01	4.07E-01	2.84E-01	9.36E-02	1.36E-02	8.14E-04	1.95E-05
7.86E+01	2.05E+02	3.81E+02	2.82E+01	3.46E-01	2.41E-01	7.92E-02	1.15E-02	7.00E-04	1.71E-05
9.31E+01	2.08E+02	3.81E+02	3.51E+01	2.88E-01	2.01E-01	6.60E-02	9.63E-03	5.92E-04	1.47E-05
1.10E+02	2.11E+02	3.81E+02	4.30E+01	2.36E-01	1.65E-01	5.41E-02	7.93E-03	4.92E-04	1.25E-05
1.31E+02	2.15E+02	3.81E+02	5.17E+01	1.92E-01	1.33E-01	4.38E-02	6.44E-03	4.03E-04	1.04E-05
1.55E+02	2.20E+02	3.81E+02	6.11E+01	1.54E-01	1.07E-01	3.52E-02	5.18E-03	3.27E-04	8.56E-06
1.83E+02	2.25E+02	3.81E+02	7.12E+01	1.23E-01	8.56E-02	2.81E-02	4.15E-03	2.64E-04	7.00E-06
2.17E+02	2.31E+02	3.81E+02	8.21E+01	9.81E-02	6.81E-02	2.23E-02	3.31E-03	2.12E-04	5.70E-06
2.58E+02	2.39E+02	3.81E+02	9.36E+01	7.74E-02	5.37E-02	1.76E-02	2.61E-03	1.68E-04	4.59E-06
3.05E+02	2.48E+02	3.81E+02	1.06E+02	6.03E-02	4.18E-02	1.37E-02	2.03E-03	1.32E-04	3.64E-06
3.62E+02	2.59E+02	3.81E+02	1.18E+02	4.65E-02	3.22E-02	1.05E-02	1.57E-03	1.03E-04	2.87E-06
4.29E+02	2.72E+02	3.81E+02	1.31E+02	3.56E-02	2.47E-02	8.07E-03	1.21E-03	7.94E-05	2.24E-06
5.09E+02	2.87E+02	3.81E+02	1.45E+02	2.72E-02	1.88E-02	6.16E-03	9.21E-04	6.10E-05	1.74E-06
6.03E+02	3.05E+02	3.81E+02	1.59E+02	2.07E-02	1.43E-02	4.69E-03	7.03E-04	4.69E-05	1.35E-06

7.16E+02	3.26E+02	3.81E+02	1.73E+02	1.58E-02	1.09E-02	3.57E-03	5.36E-04	3.60E-05	1.05E-06
8.49E+02	3.51E+02	3.81E+02	1.88E+02	1.21E-02	8.33E-03	2.72E-03	4.09E-04	2.76E-05	8.17E-07
1.01E+03	3.81E+02	3.81E+02	2.04E+02	9.22E-03	6.37E-03	2.08E-03	3.13E-04	2.13E-05	6.36E-07
1.20E+03	4.16E+02	3.82E+02	2.21E+02	7.06E-03	4.87E-03	1.59E-03	2.40E-04	1.64E-05	4.95E-07
1.43E+03	4.57E+02	3.85E+02	2.40E+02	5.41E-03	3.74E-03	1.22E-03	1.84E-04	1.26E-06	3.86E-07
1.71E+03	5.06E+02	3.91E+02	2.60E+02	4.15E-03	2.87E-03	9.34E-04	1.41E-04	9.76E-06	3.02E-07
2.06E+03	5.64E+02	4.00E+02	2.82E+02	3.18E-03	2.19E-03	7.15E-04	1.08E-04	7.52E-06	2.35E-07
2.48E+03	6.32E+02	4.11E+02	3.06E+02	2.42E-03	1.67E-03	5.43E-04	8.25E-05	5.75E-06	1.81E-07
2.99E+03	7.14E+02	4.26E+02	3.33E+02	1.82E-03	1.25E-03	4.08E-04	6.21E-05	4.35E-06	1.39E-07

1

TIME AVERAGED (TAV = 10. S) VOLUME CONCENTRATION: CONCENTRATION IN THE Z = 1.00 PLANE.

DOWNWIND DISTANCE X (M)	TIME OF MAX CONC (S)	CLOUD DURATION (S)	EFFECTIVE HALF WIDTH BBC (M)	AVERAGE CONCENTRATION (VOLUME FRACTION) AT (X,Y,Z) Y/BBC= 0.0	Y/BBC= 0.5	Y/BBC= 1.0	Y/BBC= 1.5	Y/BBC= 2.0	Y/BBC= 2.5
1.00E+00	1.91E+02	3.81E+02	4.82E-01	1.00E+00	1.00E+00	5.31E-01	1.31E-02	9.50E-06	1.57E-10
1.02E+00	1.91E+02	3.81E+02	4.83E-01	1.00E+00	1.00E+00	5.30E-01	1.33E-02	9.81E-06	1.69E-10
1.04E+00	1.91E+02	3.81E+02	4.84E-01	1.00E+00	1.00E+00	5.30E-01	1.34E-02	1.03E-05	1.86E-10
1.07E+00	1.91E+02	3.81E+02	4.85E-01	1.00E+00	1.00E+00	5.29E-01	1.36E-02	1.08E-05	2.09E-10
1.10E+00	1.91E+02	3.81E+02	4.86E-01	1.00E+00	1.00E+00	5.28E-01	1.38E-02	1.15E-05	2.39E-10
1.13E+00	1.91E+02	3.81E+02	4.88E-01	1.00E+00	1.00E+00	5.27E-01	1.41E-02	1.23E-05	2.80E-10
1.18E+00	1.91E+02	3.81E+02	4.90E-01	1.00E+00	1.00E+00	5.26E-01	1.44E-02	1.34E-05	3.37E-10
1.23E+00	1.91E+02	3.81E+02	4.92E-01	1.00E+00	1.00E+00	5.24E-01	1.48E-02	1.48E-05	4.17E-10
1.29E+00	1.91E+02	3.81E+02	4.95E-01	1.00E+00	1.00E+00	5.23E-01	1.52E-02	1.65E-05	5.35E-10
1.36E+00	1.91E+02	3.81E+02	4.98E-01	1.00E+00	1.00E+00	5.21E-01	1.57E-02	1.88E-05	7.13E-10
1.45E+00	1.91E+02	3.81E+02	5.02E-01	1.00E+00	1.00E+00	5.18E-01	1.63E-02	2.18E-05	9.92E-10
1.55E+00	1.91E+02	3.81E+02	5.06E-01	1.00E+00	1.00E+00	5.16E-01	1.71E-02	2.59E-05	1.45E-09
1.68E+00	1.91E+02	3.81E+02	5.12E-01	1.00E+00	1.00E+00	5.12E-01	1.80E-02	3.17E-05	2.28E-09
1.82E+00	1.91E+02	3.81E+02	5.19E-01	1.00E+00	1.00E+00	5.09E-01	1.90E-02	3.91E-05	3.61E-09
1.99E+00	1.91E+02	3.81E+02	5.28E-01	1.00E+00	1.00E+00	5.04E-01	2.02E-02	4.94E-05	6.08E-09
2.19E+00	1.91E+02	3.81E+02	5.38E-01	1.00E+00	1.00E+00	4.99E-01	2.16E-02	6.40E-05	1.08E-08
2.43E+00	1.91E+02	3.81E+02	5.50E-01	1.00E+00	1.00E+00	4.92E-01	2.32E-02	8.52E-05	2.05E-08
2.72E+00	1.91E+02	3.81E+02	5.66E-01	1.00E+00	1.00E+00	4.84E-01	2.49E-02	1.14E-04	3.96E-08
3.06E+00	1.91E+02	3.81E+02	5.85E-01	1.00E+00	1.00E+00	4.76E-01	2.65E-02	1.48E-04	7.09E-08
3.46E+00	1.91E+02	3.81E+02	6.08E-01	1.00E+00	1.00E+00	4.65E-01	2.83E-02	1.96E-04	1.34E-07
3.94E+00	1.91E+02	3.81E+02	6.38E-01	1.00E+00	1.00E+00	4.52E-01	3.02E-02	2.64E-04	2.63E-07
4.50E+00	1.91E+02	3.81E+02	6.74E-01	1.00E+00	1.00E+00	4.35E-01	3.22E-02	3.59E-04	5.33E-07
5.17E+00	1.91E+02	3.81E+02	7.20E-01	1.00E+00	1.00E+00	4.14E-01	3.39E-02	4.87E-04	1.09E-06
5.97E+00	1.91E+02	3.81E+02	7.79E-01	1.00E+00	1.00E+00	3.88E-01	3.49E-02	6.33E-04	2.07E-06
6.91E+00	1.92E+02	3.81E+02	8.70E-01	1.00E+00	1.00E+00	3.46E-01	3.39E-02	7.50E-04	3.40E-06
8.03E+00	1.92E+02	3.81E+02	1.04E+00	1.00E+00	8.41E-01	2.89E-01	3.03E-02	7.94E-04	4.76E-06
9.35E+00	1.92E+02	3.81E+02	1.27E+00	9.22E-01	6.94E-01	2.37E-01	2.64E-02	8.05E-04	6.18E-06
1.09E+01	1.92E+02	3.81E+02	1.58E+00	7.77E-01	5.77E-01	1.96E-01	2.30E-02	7.98E-04	7.58E-06
1.28E+01	1.93E+02	3.81E+02	2.00E+00	6.75E-01	4.95E-01	1.67E-01	2.05E-02	7.95E-04	9.05E-06
1.50E+01	1.93E+02	3.81E+02	2.55E+00	6.13E-01	4.44E-01	1.49E-01	1.90E-02	8.08E-04	1.07E-05
1.76E+01	1.94E+02	3.81E+02	3.25E+00	5.75E-01	4.13E-01	1.39E-01	1.82E-02	8.33E-04	1.26E-05
2.07E+01	1.94E+02	3.81E+02	4.16E+00	5.48E-01	3.91E-01	1.31E-01	1.75E-02	8.56E-04	1.43E-05
2.44E+01	1.95E+02	3.81E+02	5.33E+00	5.19E-01	3.68E-01	1.23E-01	1.68E-02	8.63E-04	1.58E-05
2.88E+01	1.96E+02	3.81E+02	6.81E+00	4.85E-01	3.43E-01	1.14E-01	1.58E-02	8.48E-04	1.66E-05
3.40E+01	1.97E+02	3.81E+02	8.68E+00	4.46E-01	3.14E-01	1.04E-01	1.47E-02	8.11E-04	1.68E-05
4.02E+01	1.98E+02	3.81E+02	1.11E+01	4.05E-01	2.84E-01	9.39E-02	1.34E-02	7.60E-04	1.65E-05
4.75E+01	1.99E+02	3.81E+02	1.40E+01	3.62E-01	2.54E-01	8.38E-02	1.20E-02	6.98E-04	1.58E-05
5.62E+01	2.01E+02	3.81E+02	1.78E+01	3.21E-01	2.25E-01	7.40E-02	1.07E-02	6.32E-04	1.47E-05
6.64E+01	2.03E+02	3.81E+02	2.24E+01	2.82E-01	1.97E-01	6.48E-02	9.40E-03	5.64E-04	1.35E-05
7.86E+01	2.05E+02	3.81E+02	2.82E+01	2.50E-01	1.75E-01	5.75E-02	8.36E-03	5.08E-04	1.24E-05
9.31E+01	2.08E+02	3.81E+02	3.51E+01	2.20E-01	1.53E-01	5.04E-02	7.37E-03	4.52E-04	1.13E-05
1.10E+02	2.11E+02	3.81E+02	4.30E+01	1.89E-01	1.32E-01	4.33E-02	6.34E-03	3.94E-04	9.98E-06
1.31E+02	2.15E+02	3.81E+02	5.17E+01	1.60E-01	1.11E-01	3.65E-02	5.36E-03	3.36E-04	8.64E-06
1.55E+02	2.20E+02	3.81E+02	6.11E+01	1.33E-01	9.22E-02	3.02E-02	4.46E-03	2.81E-04	7.36E-06
1.83E+02	2.25E+02	3.81E+02	7.12E+01	1.09E-01	7.57E-02	2.48E-02	3.67E-03	2.33E-04	6.19E-06
2.17E+02	2.31E+02	3.81E+02	8.21E+01	8.88E-02	6.16E-02	2.02E-02	2.99E-03	1.92E-04	5.16E-06
2.58E+02	2.39E+02	3.81E+02	9.36E+01	7.15E-02	4.96E-02	1.63E-02	2.41E-03	1.56E-04	4.24E-06
3.05E+02	2.48E+02	3.81E+02	1.06E+02	5.67E-02	3.93E-02	1.29E-02	1.91E-03	1.24E-04	3.43E-06
3.62E+02	2.59E+02	3.81E+02	1.18E+02	4.44E-02	3.08E-02	1.01E-02	1.50E-03	9.82E-05	2.74E-06
4.29E+02	2.72E+02	3.81E+02	1.31E+02	3.44E-02	2.38E-02	7.80E-03	1.17E-03	7.67E-05	2.17E-06
5.09E+02	2.87E+02	3.81E+02	1.45E+02	2.65E-02	1.84E-02	6.00E-03	8.99E-04	5.95E-05	1.70E-06
6.03E+02	3.05E+02	3.81E+02	1.59E+02	2.04E-02	1.41E-02	4.60E-03	6.90E-04	4.60E-05	1.33E-06

7.16E+02	3.26E+02	3.81E+02	1.73E+02	1.56E-02	1.08E-02	3.52E-03	5.29E-04	3.55E-05	1.04E-06
8.49E+02	3.51E+02	3.81E+02	1.88E+02	1.19E-02	8.26E-03	2.70E-03	4.06E-04	2.74E-05	8.09E-07
1.01E+03	3.81E+02	3.81E+02	2.04E+02	9.16E-03	6.32E-03	2.06E-03	3.11E-04	2.11E-05	6.31E-07
1.20E+03	4.16E+02	3.82E+02	2.21E+02	7.03E-03	4.85E-03	1.58E-03	2.39E-04	1.63E-05	4.93E-07
1.43E+03	4.57E+02	3.85E+02	2.40E+02	5.40E-03	3.72E-03	1.21E-03	1.84E-04	1.26E-05	3.85E-07
1.71E+03	5.06E+02	3.91E+02	2.60E+02	4.14E-03	2.86E-03	9.32E-04	1.41E-04	9.74E-06	3.01E-07
2.06E+03	5.64E+02	4.00E+02	2.82E+02	3.18E-03	2.19E-03	7.13E-04	1.08E-04	7.51E-06	2.34E-07
2.48E+03	6.32E+02	4.11E+02	3.06E+02	2.42E-03	1.67E-03	5.42E-04	8.24E-05	5.75E-06	1.81E-07
2.99E+03	7.14E+02	4.26E+02	3.33E+02	1.82E-03	1.25E-03	4.08E-04	6.20E-05	4.35E-06	1.38E-07

1

TIME AVERAGED (TAV = 10. S) VOLUME CONCENTRATION: MAXIMUM CONCENTRATION (VOLUME FRACTION) ALONG CENTERLINE.

DOWNWIND DISTANCE X (M)	HEIGHT Z (M)	MAXIMUM CONCENTRATION C(X,0,Z)	TIME OF MAX CONC (S)	CLOUD DURATION (S)
1.00E+00	1.00E+00	1.00E+00	1.91E+02	3.81E+02
1.02E+00	1.00E+00	1.00E+00	1.91E+02	3.81E+02
1.04E+00	1.00E+00	1.00E+00	1.91E+02	3.81E+02
1.07E+00	1.00E+00	1.00E+00	1.91E+02	3.81E+02
1.10E+00	1.00E+00	1.00E+00	1.91E+02	3.81E+02
1.13E+00	1.00E+00	1.00E+00	1.91E+02	3.81E+02
1.18E+00	1.00E+00	1.00E+00	1.91E+02	3.81E+02
1.23E+00	1.00E+00	1.00E+00	1.91E+02	3.81E+02
1.29E+00	1.00E+00	1.00E+00	1.91E+02	3.81E+02
1.36E+00	9.99E-01	1.00E+00	1.91E+02	3.81E+02
1.45E+00	9.99E-01	1.00E+00	1.91E+02	3.81E+02
1.55E+00	9.98E-01	1.00E+00	1.91E+02	3.81E+02
1.68E+00	9.97E-01	1.00E+00	1.91E+02	3.81E+02
1.82E+00	9.96E-01	1.00E+00	1.91E+02	3.81E+02
1.99E+00	9.95E-01	1.00E+00	1.91E+02	3.81E+02
2.19E+00	9.92E-01	1.00E+00	1.91E+02	3.81E+02
2.43E+00	9.88E-01	1.00E+00	1.91E+02	3.81E+02
2.72E+00	9.83E-01	1.00E+00	1.91E+02	3.81E+02
3.06E+00	9.76E-01	1.00E+00	1.91E+02	3.81E+02
3.46E+00	9.66E-01	1.00E+00	1.91E+02	3.81E+02
3.94E+00	9.51E-01	1.00E+00	1.91E+02	3.81E+02
4.50E+00	9.30E-01	1.00E+00	1.91E+02	3.81E+02
5.17E+00	9.00E-01	1.00E+00	1.91E+02	3.81E+02
5.97E+00	8.56E-01	1.00E+00	1.91E+02	3.81E+02
6.91E+00	7.87E-01	1.00E+00	1.92E+02	3.81E+02
8.03E+00	6.80E-01	1.00E+00	1.92E+02	3.81E+02
9.35E+00	4.81E-01	1.00E+00	1.92E+02	3.81E+02
1.09E+01	0.	1.00E+00	1.92E+02	3.81E+02
1.28E+01	0.	1.00E+00	1.93E+02	3.81E+02
1.50E+01	0.	1.00E+00	1.93E+02	3.81E+02
1.76E+01	0.	1.00E+00	1.94E+02	3.81E+02
2.07E+01	0.	1.00E+00	1.94E+02	3.81E+02
2.44E+01	0.	9.62E-01	1.95E+02	3.81E+02
2.88E+01	0.	8.43E-01	1.96E+02	3.81E+02
3.40E+01	0.	7.35E-01	1.97E+02	3.81E+02
4.02E+01	0.	6.38E-01	1.98E+02	3.81E+02
4.75E+01	0.	5.52E-01	1.99E+02	3.81E+02
5.62E+01	0.	4.75E-01	2.01E+02	3.81E+02
6.64E+01	0.	4.07E-01	2.03E+02	3.81E+02
7.86E+01	0.	3.45E-01	2.05E+02	3.81E+02
9.31E+01	0.	2.88E-01	2.08E+02	3.81E+02
1.10E+02	0.	2.36E-01	2.11E+02	3.81E+02
1.31E+02	0.	1.92E-01	2.15E+02	3.81E+02
1.55E+02	0.	1.54E-01	2.20E+02	3.81E+02
1.83E+02	0.	1.23E-01	2.25E+02	3.81E+02
2.17E+02	0.	9.81E-02	2.31E+02	3.81E+02
2.58E+02	0.	7.74E-02	2.39E+02	3.81E+02
3.05E+02	0.	6.03E-02	2.48E+02	3.81E+02
3.62E+02	0.	4.65E-02	2.59E+02	3.81E+02
4.29E+02	0.	3.56E-02	2.72E+02	3.81E+02
5.09E+02	0.	2.72E-02	2.87E+02	3.81E+02
6.03E+02	0.	2.07E-02	3.05E+02	3.81E+02

7.16E+02	0.	1.58E-02	3.26E+02	3.81E+02
8.49E+02	0.	1.21E-02	3.51E+02	3.81E+02
1.01E+03	0.	9.22E-03	3.81E+02	3.81E+02
1.20E+03	0.	7.06E-03	4.16E+02	3.82E+02
1.43E+03	0.	5.41E-03	4.57E+02	3.85E+02
1.71E+03	0.	4.16E-03	5.06E+02	3.81E+02
2.06E+03	0.	3.18E-03	5.64E+02	4.00E+02
2.48E+03	0.	2.42E-03	6.32E+02	4.11E+02
2.99E+03	0.	1.82E-03	7.14E+02	4.26E+02

4.3 Instantaneous Release

This problem is a hypothetical instantaneous release of LNG vapor. The released LNG vapor is at the LNG boiling point and has a mass about equal to one-half the total mass released in the Burro 8 evaporating pool experiment (see Example Problem 4.1). The meteorological conditions used in this simulation are also those of the Burro 8 experiment. As in Problem 4.1, the heavier-than-air character of the vapor cloud is due to the low temperature of the LNG since it has a molecular weight less than that of air. Being an instantaneous release, this calculation is conducted entirely in the transient puff dispersion mode.

Input File : INPR3

```
    4
    1
0.016043
2238.
111.7
0.
509900.
3348.5
424.1
-1.
0.
111.7
0.
900.
0.
6000.
0.
10.
1000.
0.
0.
0.
0.
.0002
2.88
1.92
306.
4.6
0.0
.0665
-1.
```

PROBLEM INPUT

IDSPL	=	4
NCALC	=	1
WMS	=	0.016043
CPS	=	2238.00
TBP	=	111.70
CMEDO	=	0.00
DHE	=	509900.
CPSL	=	3348.60
RHOSL	=	424.10
SPB	=	-1.00
SPC	=	0.00
TS	=	111.70
QS	=	0.00
AS	=	900.00
TSD	=	0.
QTIS	=	6000.00
HS	=	0.00
TAV	=	10.00
XFFM	=	1000.00
ZP(1)	=	0.00
ZP(2)	=	0.00
ZP(3)	=	0.00
ZP(4)	=	0.00
Z0	=	0.000200
ZA	=	2.88
UA	=	1.92
TA	=	306.00
RH	=	4.60
STAB	=	0.00
ALA	=	0.0665

RELEASE GAS PROPERTIES

MOLECULAR WEIGHT OF SOURCE GAS (KG)	- WMS	=	1.6043E-02
VAPOR HEAT CAPACITY, CONST. P. (J/KG-K)	- CPS	=	2.2380E+03
TEMPERATURE OF SOURCE GAS (K)	- TS	=	1.1170E+02
DENSITY OF SOURCE GAS (KG/M3)	- RHOS	=	1.7503E+00
BOILING POINT TEMPERATURE	- TBP	=	1.1170E+02
LIQUID MASS FRACTION	- CMEDO	=	0.
LIQUID HEAT CAPACITY (J/KG-K)	- CPSL	=	3.3486E+03
HEAT OF VAPORIZATION (J/KG)	- DHE	=	5.0990E+05
LIQUID SOURCE DENSITY (KG/M3)	- RHOSL	=	4.2410E+02
SATURATION PRESSURE CONSTANT	- SPA	=	8.8083E+00
SATURATION PRESSURE CONSTANT (K)	- SPB	=	9.8389E+02
SATURATION PRESSURE CONSTANT (K)	- SPC	=	0.

SPILL CHARACTERISTICS

SPILL TYPE	- IDSPL	=	4
MASS SOURCE RATE (KG/S)	- QS	=	0.
CONTINUOUS SOURCE DURATION (S)	- TSD	=	0.
CONTINUOUS SOURCE MASS (KG)	- QTCS	=	0.
INSTANTANEOUS SOURCE MASS (KG)	- QTIS	=	6.0000E+03

SOURCE AREA (M2)	- AS	= 9.0000E+02
VERTICAL VAPOR VELOCITY (M/S)	- WS	= 0.
SOURCE HALF WIDTH (M)	- BS	= 1.5000E+01
SOURCE HEIGHT (M)	- HS	= 3.8088E+00
HORIZONTAL VAPOR VELOCITY (M/S)	- US	= 0.

FIELD PARAMETERS

CONCENTRATION AVERAGING TIME (S)	- TAV	= 1.0000E+01
MIXING LAYER HEIGHT (M)	- HMX	= 7.1244E+02
MAXIMUM DOWNWIND DISTRACE (M)	- XFFM	= 1.0000E+03
CONCENTRATION MEASUREMENT HEIGHT (M)	- ZP(1)	= 0.
	- ZP(2)	= 0.
	- ZP(3)	= 0.
	- ZP(4)	= 0.

AMBIENT METEOROLOGICAL PROPERTIES

MOLECULAR WEIGHT OF AMBIENT AIR (KG)	- WMAE	= 2.8933E-02
HEAT CAPACITY OF AMBIENT AIR AT CONST P. (J/KG-K)	- CPAA	= 1.0071E+03
DENSITY OF AMBIENT AIR (KG/M3)	- RHOA	= 1.1523E+00
AMBIENT MEASUREMENT HEIGHT (M)	- ZA	= 2.8800E+00
AMBIENT ATMOSPHERIC PRESSURE (PA=N/M2=J/M3)	- PA	= 1.0132E+05
AMBIENT WIND SPEED (M/S)	- UA	= 1.9200E+00
AMBIENT TEMPERATURE (K)	- TA	= 3.0600E+02
RELATIVE HUMIDITY (PERCENT)	- RH	= 4.6000E+00
AMBIENT FRICTION VELOCITY (M/S)	- UASTR	= 7.0342E-02
ATMOSPHERIC STABILITY CLASS VALUE	- STAB	= 4.5457E+00
INVERSE MONIN-OBUKHOV LENGTH (1/M)	- ALA	= 6.6500E-02
SURFACE ROUGHNESS HEIGHT (M)	- ZO	= 2.0000E-04

ADDITIONAL PARAMETERS

SUB-STEP MULTIPLIER	- NCALC	= 1
NUMBER OF CALCULATIONAL SUB-STEPS	- NSSM	= 3
ACCELERATION OF GRAVITY (M/S2)	- GRAV	= 9.8066E+00
GAS CONSTANT (J/MOL- K)	- RR	= 8.3143E+00
VON KARMAN CONSTANT	- XK	= 4.1000E-01

1

INSTANTANEOUS SPATIALLY AVERAGED CLOUD PARAMETERS

X	ZC	H	BB	B	BBX	BX	CV	RHO	T	U	UA
0.	0.	3.81E+00	1.50E+01	1.35E+01	1.50E+01	1.35E+01	1.00E+00	1.75E+00	1.12E+02	0.	1.69E+00
2.13E-03	0.	3.80E+00	1.51E+01	1.35E+01	1.51E+01	1.35E+01	9.96E-01	1.75E+00	1.12E+02	1.39E-02	1.69E+00
9.33E-03	0.	3.76E+00	1.52E+01	1.36E+01	1.63E+01	1.36E+01	9.92E-01	1.74E+00	1.13E+02	2.90E-02	1.68E+00
2.28E-02	0.	3.68E+00	1.54E+01	1.38E+01	1.55E+01	1.38E+01	9.88E-01	1.74E+00	1.14E+02	4.50E-02	1.68E+00
4.40E-02	0.	3.56E+00	1.58E+01	1.41E+01	1.59E+01	1.41E+01	9.83E-01	1.73E+00	1.14E+02	6.19E-02	1.67E+00
7.45E-02	0.	3.39E+00	1.62E+01	1.44E+01	1.64E+01	1.44E+01	9.78E-01	1.73E+00	1.15E+02	7.95E-02	1.65E+00
1.16E-01	0.	3.19E+00	1.69E+01	1.49E+01	1.70E+01	1.49E+01	9.73E-01	1.72E+00	1.16E+02	9.77E-02	1.63E+00
1.70E-01	0.	2.95E+00	1.76E+01	1.55E+01	1.78E+01	1.55E+01	9.68E-01	1.71E+00	1.17E+02	1.16E-01	1.61E+00
2.40E-01	0.	2.70E+00	1.86E+01	1.63E+01	1.88E+01	1.63E+01	9.62E-01	1.71E+00	1.18E+02	1.36E-01	1.68E+00
3.28E-01	0.	2.43E+00	1.97E+01	1.72E+01	2.00E+01	1.72E+01	9.56E-01	1.70E+00	1.19E+02	1.55E-01	1.64E+00
4.36E-01	0.	2.17E+00	2.10E+01	1.83E+01	2.13E+01	1.82E+01	9.49E-01	1.69E+00	1.20E+02	1.76E-01	1.61E+00
5.69E-01	0.	1.92E+00	2.25E+01	1.96E+01	2.29E+01	1.95E+01	9.41E-01	1.68E+00	1.22E+02	1.98E-01	1.47E+00
7.31E-01	0.	1.69E+00	2.43E+01	2.11E+01	2.47E+01	2.09E+01	9.33E-01	1.67E+00	1.23E+02	2.22E-01	1.43E+00
9.28E-01	0.	1.49E+00	2.62E+01	2.27E+01	2.67E+01	2.25E+01	9.23E-01	1.66E+00	1.25E+02	2.48E-01	1.38E+00
1.17E+00	0.	1.31E+00	2.84E+01	2.45E+01	2.90E+01	2.42E+01	9.10E-01	1.64E+00	1.28E+02	2.78E-01	1.34E+00
1.46E+00	0.	1.16E+00	3.08E+01	2.65E+01	3.14E+01	2.61E+01	8.95E-01	1.62E+00	1.31E+02	3.13E-01	1.30E+00
1.82E+00	0.	1.03E+00	3.34E+01	2.87E+01	3.41E+01	2.82E+01	8.76E-01	1.60E+00	1.34E+02	3.53E-01	1.26E+00
2.26E+00	0.	9.36E-01	3.62E+01	3.10E+01	3.69E+01	3.04E+01	8.53E-01	1.57E+00	1.39E+02	3.99E-01	1.23E+00
2.80E+00	0.	8.62E-01	3.91E+01	3.34E+01	3.99E+01	3.27E+01	8.25E-01	1.54E+00	1.45E+02	4.50E-01	1.20E+00
3.46E+00	0.	8.09E-01	4.21E+01	3.59E+01	4.30E+01	3.50E+01	7.92E-01	1.51E+00	1.51E+02	5.06E-01	1.18E+00
4.27E+00	0.	7.74E-01	4.52E+01	3.84E+01	4.63E+01	3.74E+01	7.64E-01	1.47E+00	1.59E+02	5.64E-01	1.16E+00
5.24E+00	0.	7.52E-01	4.83E+01	4.10E+01	4.95E+01	3.98E+01	7.12E-01	1.44E+00	1.67E+02	6.24E-01	1.15E+00
6.40E+00	0.	7.43E-01	5.15E+01	4.36E+01	5.28E+01	4.23E+01	6.68E-01	1.41E+00	1.76E+02	6.83E-01	1.15E+00
7.78E+00	0.	7.44E-01	5.46E+01	4.61E+01	5.62E+01	4.46E+01	6.23E-01	1.38E+00	1.85E+02	7.41E-01	1.15E+00
9.39E+00	0.	7.53E-01	5.77E+01	4.86E+01	5.95E+01	4.69E+01	5.77E-01	1.35E+00	1.95E+02	7.96E-01	1.15E+00
1.13E+01	0.	7.70E-01	6.07E+01	5.11E+01	6.28E+01	4.92E+01	5.32E-01	1.32E+00	2.04E+02	8.49E-01	1.16E+00
1.34E+01	0.	7.94E-01	6.37E+01	5.35E+01	6.61E+01	5.14E+01	4.88E-01	1.30E+00	2.13E+02	9.00E-01	1.17E+00
1.59E+01	0.	8.26E-01	6.66E+01	5.58E+01	6.94E+01	5.36E+01	4.45E-01	1.28E+00	2.22E+02	9.49E-01	1.19E+00
1.88E+01	0.	8.64E-01	6.94E+01	5.81E+01	7.26E+01	5.56E+01	4.04E-01	1.26E+00	2.30E+02	9.95E-01	1.20E+00
2.20E+01	0.	9.09E-01	7.22E+01	6.03E+01	7.59E+01	5.76E+01	3.66E-01	1.24E+00	2.38E+02	1.04E+00	1.22E+00
2.57E+01	0.	9.61E-01	7.49E+01	6.25E+01	7.92E+01	5.95E+01	3.29E-01	1.23E+00	2.45E+02	1.08E+00	1.24E+00
2.99E+01	0.	1.02E+00	7.76E+01	6.46E+01	8.24E+01	6.14E+01	2.95E-01	1.22E+00	2.51E+02	1.12E+00	1.26E+00
3.45E+01	0.	1.08E+00	8.02E+01	6.66E+01	8.57E+01	6.32E+01	2.64E-01	1.21E+00	2.56E+02	1.16E+00	1.28E+00
3.98E+01	0.	1.16E+00	8.28E+01	6.86E+01	8.91E+01	6.49E+01	2.36E-01	1.20E+00	2.62E+02	1.20E+00	1.30E+00
4.57E+01	0.	1.24E+00	8.53E+01	7.06E+01	9.26E+01	6.66E+01	2.09E-01	1.20E+00	2.67E+02	1.23E+00	1.33E+00
5.23E+01	0.	1.34E+00	8.79E+01	7.25E+01	9.60E+01	6.82E+01	1.85E-01	1.19E+00	2.72E+02	1.27E+00	1.35E+00
5.96E+01	0.	1.44E+00	9.04E+01	7.44E+01	9.95E+01	6.98E+01	1.63E-01	1.18E+00	2.76E+02	1.31E+00	1.38E+00
6.78E+01	0.	1.57E+00	9.29E+01	7.63E+01	1.03E+02	7.14E+01	1.43E-01	1.18E+00	2.80E+02	1.34E+00	1.40E+00
7.70E+01	0.	1.70E+00	9.53E+01	7.81E+01	1.07E+02	7.29E+01	1.26E-01	1.17E+00	2.84E+02	1.38E+00	1.43E+00
8.72E+01	0.	1.86E+00	9.78E+01	7.99E+01	1.11E+02	7.43E+01	1.09E-01	1.17E+00	2.87E+02	1.41E+00	1.46E+00
9.86E+01	0.	2.03E+00	1.00E+02	8.17E+01	1.15E+02	7.57E+01	9.49E-02	1.17E+00	2.89E+02	1.44E+00	1.48E+00
1.11E+02	0.	2.22E+00	1.03E+02	8.34E+01	1.19E+02	7.70E+01	8.23E-02	1.16E+00	2.92E+02	1.48E+00	1.51E+00
1.25E+02	0.	2.43E+00	1.05E+02	8.52E+01	1.24E+02	7.83E+01	7.11E-02	1.16E+00	2.94E+02	1.51E+00	1.54E+00
1.41E+02	0.	2.67E+00	1.08E+02	8.69E+01	1.29E+02	7.96E+01	6.13E-02	1.16E+00	2.96E+02	1.55E+00	1.57E+00
1.58E+02	0.	2.93E+00	1.10E+02	8.86E+01	1.34E+02	8.08E+01	5.28E-02	1.16E+00	2.97E+02	1.58E+00	1.60E+00
1.78E+02	0.	3.23E+00	1.13E+02	9.02E+01	1.39E+02	8.19E+01	4.53E-02	1.16E+00	2.98E+02	1.61E+00	1.63E+00
1.99E+02	0.	3.55E+00	1.16E+02	9.19E+01	1.45E+02	8.30E+01	3.88E-02	1.16E+00	3.00E+02	1.65E+00	1.66E+00
2.23E+02	0.	3.90E+00	1.18E+02	9.36E+01	1.51E+02	8.41E+01	3.32E-02	1.16E+00	3.01E+02	1.68E+00	1.70E+00
2.50E+02	0.	4.30E+00	1.21E+02	9.52E+01	1.57E+02	8.51E+01	2.83E-02	1.16E+00	3.01E+02	1.71E+00	1.73E+00
2.79E+02	0.	4.73E+00	1.24E+02	9.68E+01	1.64E+02	8.61E+01	2.41E-02	1.15E+00	3.02E+02	1.75E+00	1.76E+00
3.11E+02	0.	5.21E+00	1.26E+02	9.84E+01	1.72E+02	8.71E+01	2.05E-02	1.15E+00	3.03E+02	1.78E+00	1.79E+00
3.47E+02	0.	5.73E+00	1.29E+02	1.00E+02	1.80E+02	8.80E+01	1.75E-02	1.15E+00	3.03E+02	1.82E+00	1.82E+00
3.87E+02	0.	6.30E+00	1.32E+02	1.02E+02	1.89E+02	8.88E+01	1.48E-02	1.15E+00	3.04E+02	1.85E+00	1.86E+00
4.31E+02	0.	6.93E+00	1.35E+02	1.03E+02	1.98E+02	8.96E+01	1.26E-02	1.15E+00	3.04E+02	1.88E+00	1.89E+00

4.80E+02	0.	7.61E+00	1.39E+02	1.05E+02	2.08E+02	9.04E+01	1.06E-02	1.15E+00	3.04E+02	1.92E+00	1.92E+00
5.34E+02	0.	8.36E+00	1.42E+02	1.06E+02	2.20E+02	9.11E+01	8.99E-03	1.16E+00	3.06E+02	1.95E+00	1.96E+00
5.93E+02	0.	9.16E+00	1.45E+02	1.08E+02	2.32E+02	9.17E+01	7.59E-03	1.15E+00	3.05E+02	1.98E+00	1.99E+00
6.59E+02	0.	1.00E+01	1.49E+02	1.09E+02	2.46E+02	9.24E+01	6.40E-03	1.16E+00	3.06E+02	2.02E+00	2.02E+00
7.32E+02	0.	1.10E+01	1.52E+02	1.11E+02	2.69E+02	9.29E+01	5.40E-03	1.15E+00	3.05E+02	2.05E+00	2.06E+00
8.13E+02	0.	1.20E+01	1.56E+02	1.12E+02	2.76E+02	9.35E+01	4.66E-03	1.16E+00	3.06E+02	2.08E+00	2.09E+00
9.01E+02	0.	1.31E+01	1.60E+02	1.13E+02	2.92E+02	9.39E+01	3.83E-03	1.16E+00	3.06E+02	2.12E+00	2.12E+00

1

X	CM	CMV	CMDA	CMW	CMWV	WC	VG	UG	W	V	VX
0.	1.00E+00	1.00E+00	0.	0.	0.	0.	0.	0.	4.36E-02	1.03E-01	3.52E-02
2.13E-03	9.93E-01	9.93E-01	6.62E-03	1.00E-05	1.88E-15	0.	1.95E-01	1.95E-01	2.31E-03	1.02E-01	1.72E-01
9.33E-03	9.86E-01	9.86E-01	1.37E-02	2.08E-05	2.48E-15	0.	4.02E-01	4.02E-01	2.92E-03	1.01E-01	1.72E-01
2.28E-02	9.79E-01	9.79E-01	2.14E-02	3.24E-05	3.35E-15	0.	6.18E-01	6.17E-01	3.55E-03	1.00E-01	1.71E-01
4.40E-02	9.70E-01	9.70E-01	2.95E-02	4.47E-05	4.60E-15	0.	8.39E-01	8.36E-01	4.23E-03	9.91E-02	1.70E-01
7.45E-02	9.62E-01	9.62E-01	3.81E-02	5.78E-05	6.46E-15	0.	1.06E+00	1.06E+00	4.99E-03	9.74E-02	1.68E-01
1.16E-01	9.53E-01	9.53E-01	4.71E-02	7.15E-05	9.24E-15	0.	1.28E+00	1.27E+00	5.87E-03	9.54E-02	1.65E-01
1.70E-01	9.43E-01	9.43E-01	5.66E-02	8.59E-05	1.35E-14	0.	1.48E+00	1.47E+00	6.89E-03	9.31E-02	1.63E-01
2.40E-01	9.33E-01	9.33E-01	6.66E-02	1.01E-04	2.01E-14	0.	1.67E+00	1.66E+00	8.06E-03	9.05E-02	1.59E-01
3.28E-01	9.23E-01	9.23E-01	7.72E-02	1.17E-04	3.09E-14	0.	1.84E+00	1.83E+00	9.40E-03	8.77E-02	1.66E-01
4.36E-01	9.11E-01	9.11E-01	8.86E-02	1.34E-04	4.92E-14	0.	1.99E+00	1.97E+00	1.09E-02	8.46E-02	1.52E-01
5.69E-01	8.99E-01	8.99E-01	1.01E-01	1.53E-04	8.25E-14	0.	2.11E+00	2.09E+00	1.27E-02	8.12E-02	1.48E-01
7.31E-01	8.85E-01	8.85E-01	1.16E-01	1.75E-04	1.48E-13	0.	2.21E+00	2.19E+00	1.46E-02	7.77E-02	1.44E-01
9.28E-01	8.69E-01	8.69E-01	1.31E-01	1.99E-04	2.94E-13	0.	2.28E+00	2.25E+00	1.67E-02	7.40E-02	1.40E-01
1.17E+00	8.49E-01	8.49E-01	1.51E-01	2.29E-04	6.64E-13	0.	2.32E+00	2.29E+00	1.88E-02	7.01E-02	1.37E-01
1.46E+00	8.26E-01	8.26E-01	1.74E-01	2.64E-04	1.76E-12	0.	2.33E+00	2.30E+00	2.10E-02	6.61E-02	1.34E-01
1.82E+00	7.97E-01	7.97E-01	2.02E-01	3.07E-04	5.63E-12	0.	2.30E+00	2.28E+00	2.30E-02	6.20E-02	1.31E-01
2.26E+00	7.63E-01	7.63E-01	2.37E-01	3.59E-04	2.18E-11	0.	2.25E+00	2.23E+00	2.46E-02	5.79E-02	1.29E-01
2.80E+00	7.23E-01	7.23E-01	2.76E-01	4.20E-04	1.01E-10	0.	2.16E+00	2.14E+00	2.57E-02	5.38E-02	1.27E-01
3.46E+00	6.78E-01	6.78E-01	3.21E-01	4.88E-04	5.28E-10	0.	2.05E+00	2.03E+00	2.62E-02	4.98E-02	1.26E-01
4.27E+00	6.29E-01	6.29E-01	3.70E-01	5.62E-04	2.93E-09	0.	1.92E+00	1.90E+00	2.61E-02	4.69E-02	1.26E-01
5.24E+00	5.79E-01	5.79E-01	4.21E-01	6.39E-04	1.60E-08	0.	1.78E+00	1.76E+00	2.55E-02	4.23E-02	1.24E-01
6.40E+00	5.28E-01	5.28E-01	4.72E-01	7.16E-04	8.14E-08	0.	1.63E+00	1.61E+00	2.46E-02	3.89E-02	1.24E-01
7.78E+00	4.78E-01	4.78E-01	5.21E-01	7.91E-04	3.71E-07	0.	1.48E+00	1.46E+00	2.36E-02	3.59E-02	1.24E-01
9.39E+00	4.31E-01	4.31E-01	5.68E-01	8.62E-04	1.48E-06	0.	1.34E+00	1.33E+00	2.26E-02	3.32E-02	1.24E-01
1.13E+01	3.87E-01	3.87E-01	6.12E-01	9.29E-04	5.19E-06	0.	1.21E+00	1.20E+00	2.17E-02	3.09E-02	1.25E-01
1.34E+01	3.46E-01	3.46E-01	6.53E-01	9.91E-04	1.59E-05	0.	1.09E+00	1.07E+00	2.09E-02	2.89E-02	1.25E-01
1.59E+01	3.08E-01	3.08E-01	6.91E-01	1.05E-03	4.29E-05	0.	9.77E-01	9.65E-01	2.02E-02	2.72E-02	1.26E-01
1.88E+01	2.73E-01	2.73E-01	7.25E-01	1.10E-03	1.03E-04	0.	8.76E-01	8.65E-01	1.97E-02	2.58E-02	1.27E-01
2.20E+01	2.42E-01	2.42E-01	7.57E-01	1.15E-03	2.20E-04	0.	7.86E-01	7.75E-01	1.92E-02	2.47E-02	1.28E-01
2.57E+01	2.14E-01	2.14E-01	7.85E-01	1.19E-03	4.22E-04	0.	7.05E-01	6.94E-01	1.87E-02	2.38E-02	1.29E-01
2.99E+01	1.88E-01	1.88E-01	8.10E-01	1.23E-03	7.30E-04	0.	6.33E-01	6.23E-01	1.83E-02	2.32E-02	1.30E-01
3.45E+01	1.66E-01	1.66E-01	8.33E-01	1.26E-03	1.15E-03	0.	5.70E-01	5.60E-01	1.77E-02	2.26E-02	1.31E-01
3.98E+01	1.46E-01	1.46E-01	8.53E-01	1.29E-03	1.29E-03	0.	5.16E-01	5.06E-01	1.75E-02	2.23E-02	1.33E-01
4.57E+01	1.28E-01	1.28E-01	8.71E-01	1.32E-03	1.32E-03	0.	4.67E-01	4.57E-01	1.75E-02	2.21E-02	1.35E-01
5.23E+01	1.12E-01	1.12E-01	8.87E-01	1.35E-03	1.35E-03	0.	4.22E-01	4.12E-01	1.75E-02	2.19E-02	1.36E-01
5.96E+01	9.75E-02	9.75E-02	9.01E-01	1.37E-03	1.37E-03	0.	3.82E-01	3.72E-01	1.76E-02	2.19E-02	1.38E-01
6.78E+01	8.48E-02	8.48E-02	9.14E-01	1.39E-03	1.39E-03	0.	3.46E-01	3.36E-01	1.77E-02	2.19E-02	1.41E-01
7.70E+01	7.36E-02	7.36E-02	9.25E-01	1.40E-03	1.40E-03	0.	3.14E-01	3.04E-01	1.78E-02	2.20E-02	1.43E-01
8.72E+01	6.36E-02	6.36E-02	9.35E-01	1.42E-03	1.42E-03	0.	2.85E-01	2.75E-01	1.79E-02	2.21E-02	1.46E-01
9.86E+01	5.49E-02	5.49E-02	9.44E-01	1.43E-03	1.43E-03	0.	2.60E-01	2.49E-01	1.80E-02	2.23E-02	1.48E-01
1.11E+02	4.73E-02	4.73E-02	9.51E-01	1.44E-03	1.44E-03	0.	2.37E-01	2.25E-01	1.82E-02	2.24E-02	1.51E-01
1.25E+02	4.07E-02	4.07E-02	9.58E-01	1.45E-03	1.45E-03	0.	2.16E-01	2.04E-01	1.83E-02	2.26E-02	1.54E-01
1.41E+02	3.50E-02	3.50E-02	9.64E-01	1.46E-03	1.46E-03	0.	1.97E-01	1.85E-01	1.85E-02	2.28E-02	1.57E-01
1.58E+02	3.00E-02	3.00E-02	9.69E-01	1.47E-03	1.47E-03	0.	1.80E-01	1.68E-01	1.86E-02	2.31E-02	1.60E-01
1.78E+02	2.56E-02	2.56E-02	9.73E-01	1.48E-03	1.48E-03	0.	1.65E-01	1.53E-01	1.88E-02	2.33E-02	1.64E-01
1.99E+02	2.19E-02	2.19E-02	9.77E-01	1.48E-03	1.48E-03	0.	1.51E-01	1.39E-01	1.89E-02	2.35E-02	1.67E-01
2.23E+02	1.87E-02	1.87E-02	9.80E-01	1.49E-03	1.49E-03	0.	1.39E-01	1.26E-01	1.90E-02	2.37E-02	1.71E-01
2.50E+02	1.59E-02	1.59E-02	9.83E-01	1.49E-03	1.49E-03	0.	1.27E-01	1.15E-01	1.91E-02	2.40E-02	1.74E-01
2.79E+02	1.35E-02	1.35E-02	9.85E-01	1.49E-03	1.49E-03	0.	1.17E-01	1.04E-01	1.92E-02	2.42E-02	1.78E-01
3.11E+02	1.15E-02	1.15E-02	9.87E-01	1.50E-03	1.50E-03	0.	1.07E-01	9.44E-02	1.92E-02	2.44E-02	1.81E-01
3.47E+02	9.76E-03	9.76E-03	9.89E-01	1.50E-03	1.50E-03	0.	9.87E-02	8.55E-02	1.92E-02	2.46E-02	1.85E-01
3.87E+02	8.27E-03	8.27E-03	9.90E-01	1.50E-03	1.50E-03	0.	9.06E-02	7.74E-02	1.92E-02	2.48E-02	1.88E-01
4.31E+02	7.00E-03	7.00E-03	9.91E-01	1.50E-03	1.50E-03	0.	8.31E-02	7.00E-02	1.92E-02	2.50E-02	1.92E-01
4.80E+02	5.92E-03	5.92E-03	9.93E-01	1.51E-03	1.51E-03	0.	7.62E-02	6.32E-02	1.91E-02	2.52E-02	1.95E-01
5.34E+02	5.00E-03	5.00E-03	9.93E-01	1.51E-03	1.51E-03	0.	6.97E-02	5.69E-02	1.90E-02	2.54E-02	1.98E-01
5.93E+02	4.22E-03	4.22E-03	9.94E-01	1.51E-03	1.51E-03	0.	6.37E-02	6.11E-02	1.89E-02	2.56E-02	2.02E-01

00

6.59E+02	3.56E-03	3.56E-03	9.95E-01	1.51E-03	1.51E-03	0.	5.81E-02	4.58E-02	1.87E-02	2.57E-02	2.05E-01
7.32E+02	3.00E-03	3.00E-03	9.95E-01	1.51E-03	1.51E-03	0.	5.28E-02	4.09E-02	1.85E-02	2.59E-02	2.07E-01
8.13E+02	2.53E-03	2.53E-03	9.96E-01	1.51E-03	1.51E-03	0.	4.79E-02	3.64E-02	1.83E-02	2.60E-02	2.10E-01
9.01E+02	2.13E-03	2.13E-03	9.96E-01	1.51E-03	1.51E-03	0.	4.33E-02	3.23E-02	1.81E-02	2.61E-02	2.13E-01

1

TIME AVERAGED (TAV = 10. S) VOLUME CONCENTRATION: CONCENTRATION CONTOUR PARAMETERS

C(X,Y,Z,T) = CC(T) * (ERF(XA)-ERF(XB)) * (ERF(YA)-ERF(YB)) * (EXP(-ZA*ZA)+EXP(-ZB*ZB))

```
C(X,Y,Z,T) = CONCENTRATION (VOLUME FRACTION) AT (X,Y,Z,T)
         X = DOWNWIND DISTANCE (M)
         Y = CROSSWIND HORIZONTAL DISTANCE (M)
         Z = HEIGHT (M)
         T = TIME (S)

       ERF = ERROR FUNCTON
        XA = (X-XC+BX)/(SR2*BETAX)
        XB = (X-XC-BX)/(SR2*BETAX)
        YA = (Y+B)/(SR2*BETAC)
        YB = (Y-B)/(SR2*BETAC)
       EXP = EXPONENTIAL FUNCTION
        ZA = (Z-ZC)/(SR2*SIG)
        ZB = (Z+ZC)/(SR2*SIG)
       SR2 = SQRT(2.0)
```

T	CC(T)	B(T)	BETAC(T)	ZC(T)	SIG(T)	XC(T)	BX(T)	BETAX(T)
0.	2.13E-01	1.35E+01	3.77E+00	0.	2.20E+00	0.	1.49E+01	3.77E+00
3.09E-01	2.14E-01	1.35E+01	3.83E+00	0.	2.20E+00	2.13E-03	1.49E+01	3.86E+00
6.44E-01	2.14E-01	1.36E+01	3.91E+00	0.	2.17E+00	9.33E-03	1.49E+01	3.97E+00
1.01E+00	2.15E-01	1.38E+01	4.01E+00	0.	2.12E+00	2.28E-02	1.49E+01	4.11E+00
1.40E+00	2.16E-01	1.41E+01	4.15E+00	0.	2.05E+00	4.40E-02	1.49E+01	4.29E+00
1.84E+00	2.16E-01	1.44E+01	4.32E+00	0.	1.96E+00	7.45E-02	1.49E+01	4.50E+00
2.30E+00	2.17E-01	1.49E+01	4.53E+00	0.	1.84E+00	1.16E-01	1.49E+01	4.76E+00
2.81E+00	2.18E-01	1.55E+01	4.79E+00	0.	1.71E+00	1.70E-01	1.49E+01	5.08E+00
3.37E+00	2.18E-01	1.63E+01	5.10E+00	0.	1.56E+00	2.40E-01	1.49E+01	5.45E+00
3.97E+00	2.19E-01	1.72E+01	5.47E+00	0.	1.41E+00	3.28E-01	1.49E+01	5.88E+00
4.62E+00	2.19E-01	1.83E+01	5.90E+00	0.	1.25E+00	4.36E-01	1.49E+01	6.39E+00
5.33E+00	2.20E-01	1.96E+01	6.40E+00	0.	1.11E+00	5.69E-01	1.49E+01	6.96E+00
6.10E+00	2.20E-01	2.11E+01	6.96E+00	0.	9.77E-01	7.31E-01	1.49E+01	7.62E+00
6.94E+00	2.19E-01	2.27E+01	7.60E+00	0.	8.58E-01	9.28E-01	1.49E+01	8.35E+00
7.86E+00	2.18E-01	2.45E+01	8.30E+00	0.	7.55E-01	1.17E+00	1.49E+01	9.17E+00
8.85E+00	2.16E-01	2.65E+01	9.07E+00	0.	6.68E-01	1.46E+00	1.49E+01	1.01E+01
9.93E+00	2.13E-01	2.87E+01	9.91E+00	0.	5.97E-01	1.82E+00	1.49E+01	1.11E+01
1.11E+01	2.09E-01	3.10E+01	1.08E+01	0.	5.41E-01	2.26E+00	1.49E+01	1.21E+01
1.24E+01	2.04E-01	3.34E+01	1.18E+01	0.	4.98E-01	2.80E+00	1.49E+01	1.32E+01
1.38E+01	1.97E-01	3.59E+01	1.27E+01	0.	4.67E-01	3.46E+00	1.49E+01	1.44E+01
1.53E+01	1.89E-01	3.84E+01	1.38E+01	0.	4.47E-01	4.27E+00	1.49E+01	1.57E+01
1.69E+01	1.80E-01	4.10E+01	1.48E+01	0.	4.34E-01	5.24E+00	1.49E+01	1.70E+01
1.87E+01	1.71E-01	4.36E+01	1.58E+01	0.	4.29E-01	6.40E+00	1.49E+01	1.83E+01
2.06E+01	1.60E-01	4.61E+01	1.69E+01	0.	4.29E-01	7.78E+00	1.49E+01	1.97E+01
2.27E+01	1.50E-01	4.86E+01	1.79E+01	0.	4.35E-01	9.39E+00	1.49E+01	2.11E+01
2.50E+01	1.39E-01	5.11E+01	1.89E+01	0.	4.45E-01	1.13E+01	1.49E+01	2.25E+01
2.75E+01	1.29E-01	5.35E+01	1.99E+01	0.	4.59E-01	1.34E+01	1.49E+01	2.40E+01
3.02E+01	1.19E-01	5.58E+01	2.09E+01	0.	4.77E-01	1.59E+01	1.49E+01	2.55E+01
3.31E+01	1.09E-01	5.81E+01	2.19E+01	0.	4.99E-01	1.88E+01	1.49E+01	2.70E+01
3.63E+01	9.95E-02	6.03E+01	2.29E+01	0.	5.25E-01	2.20E+01	1.49E+01	2.85E+01
3.98E+01	9.06E-02	6.25E+01	2.39E+01	0.	5.55E-01	2.57E+01	1.49E+01	3.01E+01
4.35E+01	8.22E-02	6.46E+01	2.48E+01	0.	5.89E-01	2.99E+01	1.49E+01	3.18E+01
4.76E+01	7.45E-02	6.66E+01	2.58E+01	0.	6.26E-01	3.45E+01	1.49E+01	3.35E+01
5.21E+01	6.73E-02	6.86E+01	2.67E+01	0.	6.68E-01	3.98E+01	1.49E+01	3.52E+01
5.69E+01	6.07E-02	7.06E+01	2.77E+01	0.	7.17E-01	4.57E+01	1.49E+01	3.70E+01
6.22E+01	5.45E-02	7.25E+01	2.86E+01	0.	7.72E-01	5.23E+01	1.49E+01	3.89E+01
6.79E+01	4.88E-02	7.44E+01	2.96E+01	0.	8.34E-01	5.96E+01	1.49E+01	4.09E+01

7.41E+01	4.35E-02	7.63E+01	3.06E+01	0.	9.04E-01	6.78E+01	1.49E+01	4.30E+01
8.09E+01	3.88E-02	7.81E+01	3.16E+01	0.	9.83E-01	7.70E+01	1.49E+01	4.52E+01
8.82E+01	3.45E-02	7.99E+01	3.26E+01	0.	1.07E+00	8.72E+01	1.49E+01	4.76E+01
9.62E+01	3.06E-02	8.17E+01	3.36E+01	0.	1.17E+00	9.86E+01	1.49E+01	5.00E+01
1.05E+02	2.71E-02	8.34E+01	3.46E+01	0.	1.28E+00	1.11E+02	1.49E+01	5.26E+01
1.14E+02	2.40E-02	8.52E+01	3.57E+01	0.	1.40E+00	1.25E+02	1.49E+01	5.53E+01
1.25E+02	2.12E-02	8.69E+01	3.68E+01	0.	1.54E+00	1.41E+02	1.49E+01	5.83E+01
1.36E+02	1.88E-02	8.86E+01	3.80E+01	0.	1.69E+00	1.58E+02	1.49E+01	6.14E+01
1.48E+02	1.66E-02	9.02E+01	3.92E+01	0.	1.86E+00	1.78E+02	1.49E+01	6.47E+01
1.61E+02	1.47E-02	9.19E+01	4.04E+01	0.	2.05E+00	1.99E+02	1.49E+01	6.83E+01
1.75E+02	1.30E-02	9.36E+01	4.17E+01	0.	2.25E+00	2.23E+02	1.49E+01	7.21E+01
1.91E+02	1.15E-02	9.52E+01	4.30E+01	0.	2.48E+00	2.50E+02	1.49E+01	7.62E+01
2.08E+02	1.02E-02	9.68E+01	4.44E+01	0.	2.73E+00	2.79E+02	1.49E+01	8.06E+01
2.26E+02	8.99E-03	9.84E+01	4.59E+01	0.	3.01E+00	3.11E+02	1.49E+01	8.54E+01
2.46E+02	7.98E-03	1.00E+02	4.74E+01	0.	3.31E+00	3.47E+02	1.49E+01	9.06E+01
2.68E+02	7.08E-03	1.02E+02	4.90E+01	0.	3.64E+00	3.87E+02	1.49E+01	9.60E+01
2.91E+02	6.29E-03	1.03E+02	5.07E+01	0.	4.00E+00	4.31E+02	1.49E+01	1.02E+02
3.17E+02	5.60E-03	1.05E+02	5.24E+01	0.	4.39E+00	4.80E+02	1.49E+01	1.08E+02
3.45E+02	5.00E-03	1.06E+02	5.43E+01	0.	4.82E+00	5.34E+02	1.49E+01	1.16E+02
3.75E+02	4.46E-03	1.08E+02	5.62E+01	0.	5.29E+00	5.93E+02	1.49E+01	1.23E+02
4.08E+02	3.99E-03	1.09E+02	5.82E+01	0.	5.80E+00	6.59E+02	1.49E+01	1.31E+02
4.44E+02	3.58E-03	1.11E+02	6.04E+01	0.	6.35E+00	7.32E+02	1.49E+01	1.40E+02
4.83E+02	3.21E-03	1.12E+02	6.26E+01	0.	6.94E+00	8.13E+02	1.49E+01	1.49E+02
5.25E+02	2.89E-03	1.13E+02	6.50E+01	0.	7.58E+00	9.01E+02	1.49E+01	1.59E+02

1

TIME AVERAGED (TAV = 10. S) VOLUME CONCENTRATION: CONCENTRATION IN THE Z = 0.00 PLANE.

DOWNWIND DISTANCE X (M)	TIME OF MAX CONC (S)	CLOUD DURATION (S)	EFFECTIVE HALF WIDTH BBC (M)	AVERAGE CONCENTRATION (VOLUME FRACTION) AT (X,Y,Z) Y/BBC= 0.0	Y/BBC= 0.5	Y/BBC= 1.0	Y/BBC= 1.5	Y/BBC= 2.0	Y/BBC= 2.5
0.	0.	1.46E+02	1.50E+01	1.00E+00	1.00E+00	5.89E-01	1.46E-02	1.05E-05	1.75E-10
2.13E-03	3.09E-01	1.46E+02	1.51E+01	1.00E+00	1.00E+00	5.88E-01	1.53E-02	1.24E-05	2.51E-10
9.33E-03	6.44E-01	1.46E+02	1.52E+01	1.00E+00	1.00E+00	5.87E-01	1.60E-02	1.47E-05	3.64E-10
2.28E-02	1.01E+00	1.46E+02	1.54E+01	1.00E+00	1.00E+00	5.85E-01	1.67E-02	1.75E-05	6.31E-10
4.40E-02	1.40E+00	1.46E+02	1.58E+01	1.00E+00	1.00E+00	5.83E-01	1.75E-02	2.08E-05	7.76E-10
7.45E-02	1.84E+00	1.46E+02	1.62E+01	1.00E+00	1.00E+00	5.82E-01	1.84E-02	2.47E-05	1.13E-09
1.16E-01	2.30E+00	1.46E+02	1.69E+01	1.00E+00	1.00E+00	5.80E-01	1.92E-02	2.92E-05	1.64E-09
1.70E-01	2.81E+00	1.46E+02	1.76E+01	1.00E+00	1.00E+00	5.78E-01	2.01E-02	3.44E-05	2.35E-09
2.40E-01	3.37E+00	1.46E+02	1.86E+01	1.00E+00	1.00E+00	5.76E-01	2.09E-02	4.02E-05	3.33E-09
3.28E-01	3.97E+00	1.46E+02	1.97E+01	1.00E+00	1.00E+00	5.73E-01	2.18E-02	4.67E-05	4.62E-09
4.36E-01	4.62E+00	1.46E+02	2.10E+01	1.00E+00	1.00E+00	5.70E-01	2.26E-02	5.36E-05	6.30E-09
5.69E-01	5.33E+00	1.46E+02	2.25E+01	1.00E+00	1.00E+00	5.67E-01	2.33E-02	6.11E-05	8.41E-09
7.31E-01	6.10E+00	1.46E+02	2.43E+01	1.00E+00	1.00E+00	5.63E-01	2.40E-02	6.88E-05	1.10E-08
9.28E-01	6.94E+00	1.46E+02	2.62E+01	1.00E+00	1.00E+00	5.58E-01	2.46E-02	7.67E-05	1.40E-08
1.17E+00	7.86E+00	1.46E+02	2.84E+01	1.00E+00	1.00E+00	5.52E-01	2.51E-02	8.45E-05	1.76E-08
1.46E+00	8.85E+00	1.46E+02	3.08E+01	1.00E+00	1.00E+00	5.44E-01	2.54E-02	9.20E-05	2.15E-08
1.82E+00	9.93E+00	1.46E+02	3.34E+01	1.00E+00	1.00E+00	5.33E-01	2.56E-02	9.89E-05	2.57E-08
2.26E+00	1.11E+01	1.46E+02	3.62E+01	1.00E+00	1.00E+00	5.20E-01	2.56E-02	1.05E-04	3.02E-08
2.80E+00	1.24E+01	1.46E+02	3.91E+01	1.00E+00	1.00E+00	5.04E-01	2.54E-02	1.10E-04	3.46E-08
3.46E+00	1.38E+01	1.46E+02	4.21E+01	1.00E+00	1.00E+00	4.85E-01	2.49E-02	1.14E-04	3.90E-08
4.27E+00	1.53E+01	1.46E+02	4.52E+01	1.00E+00	1.00E+00	4.63E-01	2.42E-02	1.16E-04	4.30E-08
5.24E+00	1.69E+01	1.46E+02	4.83E+01	1.00E+00	1.00E+00	4.38E-01	2.34E-02	1.17E-04	4.67E-08
6.40E+00	1.87E+01	1.46E+02	5.15E+01	1.00E+00	1.00E+00	4.12E-01	2.24E-02	1.17E-04	4.99E-08
7.78E+00	2.06E+01	1.46E+02	5.46E+01	1.00E+00	1.00E+00	3.85E-01	2.12E-02	1.15E-04	5.25E-08
9.39E+00	2.27E+01	1.46E+02	5.77E+01	1.00E+00	1.00E+00	3.58E-01	2.00E-02	1.13E-04	5.47E-08
1.13E+01	2.50E+01	1.46E+02	6.07E+01	1.00E+00	9.34E-01	3.31E-01	1.88E-02	1.10E-04	5.63E-08
1.34E+01	2.75E+01	1.46E+02	6.37E+01	9.91E-01	8.59E-01	3.04E-01	1.75E-02	1.06E-04	5.76E-08
1.59E+01	3.02E+01	1.46E+02	6.66E+01	9.09E-01	7.87E-01	2.78E-01	1.62E-02	1.01E-04	5.82E-08
1.88E+01	3.31E+01	1.46E+02	6.94E+01	8.30E-01	7.17E-01	2.54E-01	1.50E-02	9.67E-05	5.85E-08
2.20E+01	3.63E+01	1.46E+02	7.22E+01	7.54E-01	6.51E-01	2.30E-01	1.38E-02	9.17E-05	5.85E-08
2.57E+01	3.98E+01	1.46E+02	7.49E+01	6.83E-01	5.88E-01	2.08E-01	1.26E-02	8.66E-05	5.82E-08
2.99E+01	4.35E+01	1.47E+02	7.76E+01	6.16E-01	5.29E-01	1.87E-01	1.15E-02	8.15E-05	5.77E-08
3.45E+01	4.76E+01	1.48E+02	8.02E+01	5.54E-01	4.75E-01	1.68E-01	1.04E-02	7.66E-05	5.71E-08
3.98E+01	5.21E+01	1.49E+02	8.28E+01	4.98E-01	4.25E-01	1.50E-01	9.46E-03	7.18E-05	5.65E-08
4.57E+01	5.69E+01	1.50E+02	8.53E+01	4.45E-01	3.79E-01	1.34E-01	8.55E-03	6.71E-05	5.58E-08
5.23E+01	6.22E+01	1.51E+02	8.79E+01	3.96E-01	3.37E-01	1.19E-01	7.70E-03	6.25E-05	5.50E-08
5.96E+01	6.79E+01	1.53E+02	9.04E+01	3.51E-01	2.98E-01	1.05E-01	6.90E-03	5.81E-05	5.43E-08
6.78E+01	7.41E+01	1.54E+02	9.29E+01	3.10E-01	2.62E-01	9.23E-02	6.17E-03	5.39E-05	5.35E-08
7.70E+01	8.09E+01	1.56E+02	9.53E+01	2.73E-01	2.30E-01	8.09E-02	5.49E-03	4.99E-05	5.27E-08
8.72E+01	8.82E+01	1.57E+02	9.78E+01	2.39E-01	2.01E-01	7.07E-02	4.88E-03	4.61E-05	5.20E-08
9.86E+01	9.62E+01	1.59E+02	1.00E+02	2.09E-01	1.76E-01	6.16E-02	4.32E-03	4.26E-05	5.14E-08
1.11E+02	1.05E+02	1.61E+02	1.03E+02	1.83E-01	1.53E-01	5.35E-02	3.82E-03	3.93E-05	5.09E-08
1.25E+02	1.14E+02	1.64E+02	1.05E+02	1.59E-01	1.32E-01	4.63E-02	3.37E-03	3.62E-05	5.05E-08
1.41E+02	1.25E+02	1.66E+02	1.08E+02	1.38E-01	1.14E-01	4.00E-02	2.97E-03	3.34E-05	5.02E-08
1.58E+02	1.36E+02	1.69E+02	1.10E+02	1.19E-01	9.86E-02	3.45E-02	2.61E-03	3.08E-05	5.00E-08
1.78E+02	1.48E+02	1.72E+02	1.13E+02	1.03E-01	8.48E-02	2.96E-02	2.29E-03	2.83E-05	4.99E-08
1.99E+02	1.61E+02	1.75E+02	1.16E+02	8.88E-02	7.28E-02	2.54E-02	2.00E-03	2.61E-05	5.00E-08
2.23E+02	1.75E+02	1.79E+02	1.18E+02	7.64E-02	6.23E-02	2.17E-02	1.75E-03	2.40E-05	5.01E-08
2.50E+02	1.91E+02	1.83E+02	1.21E+02	6.56E-02	5.33E-02	1.86E-02	1.53E-03	2.21E-05	5.04E-08
2.79E+02	2.08E+02	1.88E+02	1.24E+02	5.63E-02	4.55E-02	1.58E-02	1.33E-03	2.04E-05	5.07E-08
3.11E+02	2.26E+02	1.93E+02	1.26E+02	4.81E-02	3.87E-02	1.34E-02	1.16E-03	1.87E-05	5.11E-08
3.47E+02	2.46E+02	1.98E+02	1.29E+02	4.11E-02	3.29E-02	1.14E-02	1.01E-03	1.72E-05	5.16E-08

3.87E+02	2.68E+02	2.04E+02	1.32E+02
4.31E+02	2.91E+02	2.10E+02	1.35E+02
4.80E+02	3.17E+02	2.17E+02	1.39E+02
5.34E+02	3.45E+02	2.25E+02	1.42E+02
5.93E+02	3.76E+02	2.34E+02	1.46E+02
6.59E+02	4.08E+02	2.43E+02	1.49E+02
7.32E+02	4.44E+02	2.53E+02	1.52E+02
8.13E+02	4.83E+02	2.64E+02	1.56E+02
9.01E+02	5.26E+02	2.76E+02	1.60E+02

3.51E-02	2.79E-02	9.67E-03	8.72E-04	1.58E-05	5.21E-08
2.99E-02	2.36E-02	8.18E-03	7.66E-04	1.46E-05	5.26E-08
2.55E-02	2.00E-02	6.91E-03	6.54E-04	1.34E-05	5.32E-08
2.16E-02	1.69E-02	5.83E-03	5.55E-04	1.22E-05	5.37E-08
1.84E-02	1.43E-02	4.91E-03	4.68E-04	1.12E-05	5.42E-08
1.56E-02	1.20E-02	4.13E-03	4.20E-04	1.02E-05	5.45E-08
1.32E-02	1.01E-02	3.47E-03	3.62E-04	9.35E-06	5.48E-08
1.12E-02	8.50E-03	2.91E-03	3.11E-04	8.52E-06	5.49E-08
9.44E-03	7.14E-03	2.44E-03	2.67E-04	7.75E-06	5.48E-08

1

TIME AVERAGED (TAV = 10. S) VOLUME CONCENTRATION: MAXIMUM CONCENTRATION (VOLUME FRACTION) ALONG CENTERLINE.

DOWNWIND DISTANCE X (M)	HEIGHT Z (M)	MAXIMUM CONCENTRATION C(X,0,Z)	TIME OF MAX CONC (S)	CLOUD DURATION (S)
0.	0.	1.00E+00	0.	1.46E+02
2.13E-03	0.	1.00E+00	3.09E-01	1.46E+02
9.33E-03	0.	1.00E+00	6.44E-01	1.46E+02
2.28E-02	0.	1.00E+00	1.01E+00	1.46E+02
4.40E-02	0.	1.00E+00	1.40E+00	1.46E+02
7.45E-02	0.	1.00E+00	1.84E+00	1.46E+02
1.16E-01	0.	1.00E+00	2.30E+00	1.46E+02
1.70E-01	0.	1.00E+00	2.81E+00	1.46E+02
2.40E-01	0.	1.00E+00	3.37E+00	1.46E+02
3.28E-01	0.	1.00E+00	3.97E+00	1.46E+02
4.36E-01	0.	1.00E+00	4.62E+00	1.46E+02
5.69E-01	0.	1.00E+00	5.33E+00	1.46E+02
7.31E-01	0.	1.00E+00	6.10E+00	1.46E+02
9.28E-01	0.	1.00E+00	6.94E+00	1.46E+02
1.17E+00	0.	1.00E+00	7.86E+00	1.46E+02
1.46E+00	0.	1.00E+00	8.85E+00	1.46E+02
1.82E+00	0.	1.00E+00	9.93E+00	1.46E+02
2.26E+00	0.	1.00E+00	1.11E+01	1.46E+02
2.80E+00	0.	1.00E+00	1.24E+01	1.46E+02
3.46E+00	0.	1.00E+00	1.38E+01	1.46E+02
4.27E+00	0.	1.00E+00	1.53E+01	1.46E+02
5.24E+00	0.	1.00E+00	1.69E+01	1.46E+02
6.40E+00	0.	1.00E+00	1.87E+01	1.46E+02
7.78E+00	0.	1.00E+00	2.06E+01	1.46E+02
9.39E+00	0.	1.00E+00	2.27E+01	1.46E+02
1.13E+01	0.	1.00E+00	2.50E+01	1.46E+02
1.34E+01	0.	9.91E-01	2.75E+01	1.46E+02
1.59E+01	0.	9.09E-01	3.02E+01	1.46E+02
1.88E+01	0.	8.30E-01	3.31E+01	1.46E+02
2.20E+01	0.	7.54E-01	3.63E+01	1.46E+02
2.57E+01	0.	6.83E-01	3.98E+01	1.46E+02
2.99E+01	0.	6.16E-01	4.35E+01	1.47E+02
3.45E+01	0.	5.54E-01	4.76E+01	1.48E+02
3.98E+01	0.	4.98E-01	5.21E+01	1.49E+02
4.57E+01	0.	4.45E-01	5.69E+01	1.50E+02
5.23E+01	0.	3.96E-01	6.22E+01	1.51E+02
5.96E+01	0.	3.51E-01	6.79E+01	1.53E+02
6.78E+01	0.	3.10E-01	7.41E+01	1.54E+02
7.70E+01	0.	2.73E-01	8.09E+01	1.56E+02
8.72E+01	0.	2.39E-01	8.82E+01	1.57E+02
9.86E+01	0.	2.09E-01	9.62E+01	1.59E+02
1.11E+02	0.	1.83E-01	1.05E+02	1.61E+02
1.25E+02	0.	1.59E-01	1.14E+02	1.64E+02
1.41E+02	0.	1.38E-01	1.25E+02	1.66E+02
1.58E+02	0.	1.19E-01	1.36E+02	1.69E+02
1.78E+02	0.	1.03E-01	1.48E+02	1.72E+02
1.99E+02	0.	8.88E-02	1.61E+02	1.75E+02
2.23E+02	0.	7.64E-02	1.75E+02	1.79E+02
2.50E+02	0.	6.56E-02	1.91E+02	1.83E+02
2.79E+02	0.	5.63E-02	2.08E+02	1.88E+02
3.11E+02	0.	4.81E-02	2.26E+02	1.93E+02
3.47E+02	0.	4.11E-02	2.46E+02	1.98E+02

3.87E+02	0.	3.51E-02	2.68E+02	2.04E+02
4.31E+02	0.	2.99E-02	2.91E+02	2.10E+02
4.80E+02	0.	2.55E-02	3.17E+02	2.17E+02
5.34E+02	0.	2.16E-02	3.45E+02	2.25E+02
5.93E+02	0.	1.84E-02	3.75E+02	2.34E+02
6.59E+02	0.	1.56E-02	4.08E+02	2.43E+02
7.32E+02	0.	1.32E-02	4.44E+02	2.53E+02
8.13E+02	0.	1.12E-02	4.83E+02	2.64E+02
9.01E+02	0.	9.44E-03	5.25E+02	2.76E+02

4.4 Vertical Jet Release

This problem is a hypothetical release of vapor chlorine from a vertical jet. Since chlorine has a molecular weight greater than that of air, the resulting cloud is denser-than-air at all concentrations. The SLAB dispersion calculation begins with the plume rise calculation which extends over a short downwind distance (from $x = 1.00$ m to $x = 1.01$ m), although the plume is predicted to rise from the release height of $Z_c = 1.00$ m at $x = 1.00$ m to a maximum height of $Z_c = 2.24$ m at $x = 1.01$ m. Beyond the plume rise region, the SLAB dispersion calculation continues in the steady state plume mode until the release is terminated at $t = 300$ s. At this time, the dispersion calculation changes to the transient puff mode for the duration of the simulation.

Input File : INPR4

```
   3
   1
0.070906
498.1
239.1
0.88
287840.
926.3
1574.
1978.34
-27.01
239.1
3.33
.02
300.
0.
1.
1.
10000.
1.
0.
0.
0.
.1
10.
1.
276.
30.
4.
-1.
```

```
PROBLEM INPUT

  IDSPL  =         3
  NCALC  =         1
  WMS    =  0.070906
  CPS    =    498.10
  TBP    =    239.10
  CMEDO  =      0.88
  DHE    =   287840.
  CPSL   =    926.30
  RHOSL  =   1574.00
  SPB    =   1978.34
  SPC    =    -27.01
  TS     =    239.10
  QS     =      3.33
  AS     =      0.02
  TSD    =      300.
  QTIS   =      0.00
  HS     =      1.00
  TAV    =      1.00
  XFFM   =  10000.00
  ZP(1)  =      1.00
  ZP(2)  =      0.00
  ZP(3)  =      0.00
  ZP(4)  =      0.00
  Z0     =  0.100000
  ZA     =     10.00
  UA     =      1.00
  TA     =    276.00
  RH     =     30.00
  STAB   =      4.00

RELEASE GAS PROPERTIES

 MOLECULAR WEIGHT OF SOURCE GAS (KG)             - WMS   =  7.0906E-02
 VAPOR HEAT CAPACITY, CONST. P.  (J/KG-K)        - CPS   =  4.9810E+02
 TEMPERATURE OF SOURCE GAS (K)                   - TS    =  2.3910E+02
 DENSITY OF SOURCE GAS (KG/M3)                   - RHOS  =  3.6140E+00
 BOILING POINT TEMPERATURE                       - TBP   =  2.3910E+02
 LIQUID MASS FRACTION                            - CMEDO=   8.8000E-01
 LIQUID HEAT CAPACITY (J/KG-K)                   - CPSL  =  9.2630E+02
 HEAT OF VAPORIZATION (J/KG)                     - DHE   =  2.8784E+05
 LIQUID SOURCE DENSITY (KG/M3)                   - RHOSL=   1.5740E+03
 SATURATION PRESSURE CONSTANT                    - SPA   =  9.3278E+00
 SATURATION PRESSURE CONSTANT (K)                - SPB   =  1.9783E+03
 SATURATION PRESSURE CONSTANT (K)                - SPC   = -2.7010E+01

SPILL CHARACTERISTICS

 SPILL TYPE                                      - IDSPL=            3
 MASS SOURCE RATE (KG/S)                         - QS    =  3.3300E+00
 CONTINUOUS SOURCE DURATION (S)                  - TSD   =  3.0000E+02
 CONTINUOUS SOURCE MASS (KG)                     - QTCS  =  9.9900E+02
 INSTANTANEOUS SOURCE MASS (KG)                  - QTIS  =  0.
 SOURCE AREA (M2)                                - AS    =  2.0000E-02
```

VERTICAL VAPOR VELOCITY (M/S)	- WS	= 5.6215E+00
SOURCE HALF WIDTH (M)	- BS	= 7.0711E-02
SOURCE HEIGHT (M)	- HS	= 1.0000E+00
HORIZONTAL VAPOR VELOCITY (M/S)	- US	= 0.

FIELD PARAMETERS

CONCENTRATION AVERAGING TIME (S)	- TAV	= 1.0000E+00
MIXING LAYER HEIGHT (M)	- HMX	= 1.0400E+03
MAXIMUM DOWNWIND DISTRACE (M)	- XFFM	= 1.0000E+04
CONCENTRATION MEASUREMENT HEIGHT (M)	- ZP(1)	= 1.0000E+00
	- ZP(2)	= 0.
	- ZP(3)	= 0.
	- ZP(4)	= 0.

AMBIENT METEOROLOGICAL PROPERTIES

MOLECULAR WEIGHT OF AMBIENT AIR (KG)	- WMAE	= 2.8936E-02
HEAT CAPACITY OF AMBIENT AIR AT CONST P. (J/KG-K)	- CPAA	= 1.0070E+03
DENSITY OF AMBIENT AIR (KG/M3)	- RHOA	= 1.2777E+00
AMBIENT MEASUREMENT HEIGHT (M)	- ZA	= 1.0000E+01
AMBIENT ATMOSPHERIC PRESSURE (PA=N/M2=J/M3)	- PA	= 1.0132E+05
AMBIENT WIND SPEED (M/S)	- UA	= 1.0000E+00
AMBIENT TEMPERATURE (K)	- TA	= 2.7600E+02
RELATIVE HUMIDITY (PERCENT)	- RH	= 3.0000E+01
AMBIENT FRICTION VELOCITY (M/S)	- UASTR	= 8.9215E-02
ATMOSPHERIC STABILITY CLASS VALUE	- STAB	= 4.0000E+00
INVERSE MONIN-OBUKHOV LENGTH (1/M)	- ALA	= 0.
SURFACE ROUGHNESS HEIGHT (M)	- ZO	= 1.0000E-01

ADDITIONAL PARAMETERS

SUB-STEP MULTIPLIER	- NCALC	= 1
NUMBER OF CALCULATIONAL SUB-STEPS	- NSSM	= 3
ACCELERATION OF GRAVITY (M/S2)	- GRAV	= 9.8066E+00
GAS CONSTANT (J/MOL- K)	- RR	= 8.3143E+00
VON KARMAN CONSTANT	- XK	= 4.1000E-01

INSTANTANEOUS SPATIALLY AVERAGED CLOUD PARAMETERS

X	ZC	H	BB	B	BBX	BX	CV	RHO	T	U	UA
1.00E+00	1.00E+00	1.41E-01	7.07E-02	6.36E-02	0.	0.	1.00E+00	-1.00E+00	-1.00E+00	0.	6.76E-01
1.01E+00	2.24E+00	2.42E+00	1.21E+00	7.90E-01	1.10E-02	1.10E-02	3.11E-01	3.03E+00	2.06E+02	3.57E-01	6.76E-01
1.03E+00	2.23E+00	2.42E+00	1.21E+00	7.90E-01	3.24E-02	3.24E-02	3.11E-01	3.02E+00	2.05E+02	3.58E-01	6.76E-01
1.06E+00	2.19E+00	2.42E+00	1.21E+00	7.91E-01	5.85E-02	5.85E-02	3.11E-01	3.02E+00	2.05E+02	3.57E-01	6.75E-01
1.09E+00	2.10E+00	2.43E+00	1.22E+00	7.91E-01	9.03E-02	9.02E-02	3.10E-01	3.02E+00	2.05E+02	3.57E-01	6.72E-01
1.13E+00	1.92E+00	2.44E+00	1.22E+00	7.92E-01	1.29E-01	1.29E-01	3.09E-01	3.01E+00	2.05E+02	3.56E-01	6.68E-01
1.18E+00	1.62E+00	2.45E+00	1.23E+00	7.92E-01	1.76E-01	1.76E-01	3.08E-01	3.01E+00	2.05E+02	3.53E-01	6.60E-01
1.24E+00	1.12E+00	2.29E+00	1.33E+00	8.59E-01	2.33E-01	2.33E-01	3.07E-01	3.00E+00	2.05E+02	3.49E-01	6.49E-01
1.31E+00	6.97E-01	1.39E+00	2.15E+00	1.38E+00	3.02E-01	3.02E-01	3.04E-01	2.98E+00	2.05E+02	3.61E-01	5.73E-01
1.39E+00	4.64E-01	9.27E-01	3.24E+00	2.08E+00	3.86E-01	3.86E-01	2.94E-01	2.91E+00	2.05E+02	3.76E-01	4.84E-01
1.49E+00	3.36E-01	6.73E-01	4.47E+00	2.87E+00	4.88E-01	4.88E-01	2.67E-01	2.75E+00	2.04E+02	4.27E-01	4.16E-01
1.62E+00	2.68E-01	5.37E-01	5.26E+00	3.37E+00	6.12E-01	6.12E-01	2.21E-01	2.50E+00	2.03E+02	5.76E-01	3.86E-01
1.77E+00	2.30E-01	5.50E-01	6.15E+00	3.93E+00	7.63E-01	7.63E-01	1.74E-01	2.27E+00	2.03E+02	6.37E-01	3.54E-01
1.96E+00	2.01E-01	6.05E-01	7.05E+00	4.51E+00	9.46E-01	9.46E-01	1.42E-01	2.12E+00	2.02E+02	6.37E-01	3.57E-01
2.18E+00	1.78E-01	6.84E-01	7.99E+00	5.11E+00	1.17E+00	1.17E+00	1.19E-01	1.93E+00	2.16E+02	6.37E-01	3.62E-01
2.46E+00	1.59E-01	7.62E-01	9.00E+00	5.75E+00	1.44E+00	1.44E+00	1.01E-01	1.79E+00	2.26E+02	6.37E-01	3.68E-01
2.79E+00	1.42E-01	8.13E-01	1.01E+01	6.43E+00	1.77E+00	1.77E+00	8.67E-02	1.69E+00	2.35E+02	6.37E-01	3.74E-01
3.20E+00	1.28E-01	8.72E-01	1.13E+01	7.16E+00	2.17E+00	2.17E+00	7.47E-02	1.61E+00	2.43E+02	6.37E-01	3.80E-01
3.69E+00	1.16E-01	9.45E-01	1.25E+01	7.97E+00	2.65E+00	2.65E+00	6.44E-02	1.55E+00	2.48E+02	6.26E-01	3.88E-01
4.29E+00	1.04E-01	1.03E+00	1.40E+01	8.87E+00	3.24E+00	3.24E+00	5.57E-02	1.51E+00	2.53E+02	6.07E-01	3.97E-01
5.02E+00	9.31E-02	1.11E+00	1.57E+01	9.90E+00	3.96E+00	3.96E+00	4.83E-02	1.47E+00	2.56E+02	5.88E-01	4.06E-01
5.90E+00	8.33E-02	1.20E+00	1.76E+01	1.11E+01	4.83E+00	4.83E+00	4.19E-02	1.44E+00	2.59E+02	5.68E-01	4.15E-01
6.97E+00	7.42E-02	1.29E+00	1.98E+01	1.25E+01	5.89E+00	5.89E+00	3.62E-02	1.42E+00	2.62E+02	5.47E-01	4.24E-01
8.28E+00	6.58E-02	1.39E+00	2.24E+01	1.41E+01	7.18E+00	7.18E+00	3.13E-02	1.39E+00	2.65E+02	5.25E-01	4.34E-01
9.87E+00	5.81E-02	1.49E+00	2.55E+01	1.60E+01	8.75E+00	8.75E+00	2.69E-02	1.37E+00	2.67E+02	5.02E-01	4.44E-01
1.18E+01	5.10E-02	1.60E+00	2.92E+01	1.82E+01	1.06E+01	1.06E+01	2.31E-02	1.36E+00	2.69E+02	4.81E-01	4.54E-01
1.41E+01	4.47E-02	1.66E+00	3.34E+01	2.08E+01	1.30E+01	1.30E+01	1.96E-02	1.34E+00	2.70E+02	4.78E-01	4.60E-01
1.70E+01	3.93E-02	1.75E+00	3.82E+01	2.36E+01	1.58E+01	1.58E+01	1.64E-02	1.33E+00	2.72E+02	4.78E-01	4.68E-01
2.04E+01	3.47E-02	1.86E+00	4.34E+01	2.68E+01	1.92E+01	1.92E+01	1.35E-02	1.32E+00	2.73E+02	4.81E-01	4.78E-01
2.46E+01	3.09E-02	1.99E+00	4.90E+01	3.01E+01	2.33E+01	2.33E+01	1.11E-02	1.31E+00	2.73E+02	4.88E-01	4.88E-01
2.98E+01	2.76E-02	2.14E+00	5.50E+01	3.36E+01	2.84E+01	2.84E+01	9.00E-03	1.30E+00	2.74E+02	4.98E-01	5.01E-01
3.60E+01	2.49E-02	2.33E+00	6.13E+01	3.73E+01	3.45E+01	3.45E+01	7.25E-03	1.30E+00	2.75E+02	5.10E-01	5.15E-01
4.35E+01	2.26E-02	2.56E+00	6.80E+01	4.11E+01	4.19E+01	4.19E+01	5.79E-03	1.29E+00	2.75E+02	5.25E-01	5.31E-01
5.27E+01	2.06E-02	2.84E+00	7.49E+01	4.50E+01	5.10E+01	5.10E+01	4.59E-03	1.29E+00	2.75E+02	5.43E-01	5.49E-01
6.38E+01	1.89E-02	3.18E+00	8.21E+01	4.91E+01	6.20E+01	6.20E+01	3.61E-03	1.29E+00	2.76E+02	5.63E-01	5.70E-01
7.74E+01	1.74E-02	3.59E+00	8.97E+01	5.32E+01	7.53E+01	7.53E+01	2.81E-03	1.28E+00	2.76E+02	5.86E-01	5.92E-01
9.38E+01	1.62E-02	4.10E+00	9.75E+01	5.74E+01	9.16E+01	9.16E+01	2.18E-03	1.28E+00	2.76E+02	6.11E-01	6.17E-01
1.14E+02	1.40E-02	4.64E+00	1.06E+02	6.17E+01	1.06E+02	9.90E+01	1.53E-03	1.28E+00	2.76E+02	6.37E-01	6.41E-01
1.40E+02	1.23E-02	5.51E+00	1.14E+02	6.58E+01	1.22E+02	1.06E+02	1.04E-03	1.28E+00	2.76E+02	6.72E-01	6.74E-01
1.74E+02	1.10E-02	6.76E+00	1.22E+02	6.97E+01	1.39E+02	1.12E+02	6.94E-04	1.28E+00	2.76E+02	7.14E-01	7.15E-01
2.17E+02	9.96E-03	8.45E+00	1.30E+02	7.35E+01	1.59E+02	1.17E+02	4.56E-04	1.28E+00	2.76E+02	7.59E-01	7.60E-01
2.73E+02	9.12E-03	1.07E+01	1.39E+02	7.73E+01	1.81E+02	1.21E+02	2.97E-04	1.28E+00	2.76E+02	8.07E-01	8.07E-01
3.45E+02	8.41E-03	1.35E+01	1.49E+02	8.11E+01	2.07E+02	1.25E+02	1.93E-04	1.28E+00	2.76E+02	8.56E-01	8.56E-01
4.38E+02	7.80E-03	1.70E+01	1.59E+02	8.50E+01	2.36E+02	1.29E+02	1.24E-04	1.28E+00	2.76E+02	9.05E-01	9.05E-01
5.58E+02	7.27E-03	2.15E+01	1.71E+02	8.90E+01	2.71E+02	1.32E+02	8.00E-05	1.28E+00	2.76E+02	9.54E-01	9.54E-01
7.10E+02	6.80E-03	2.70E+01	1.85E+02	9.31E+01	3.12E+02	1.36E+02	5.13E-05	1.28E+00	2.76E+02	1.00E+00	1.00E+00
9.04E+02	6.38E-03	3.39E+01	2.00E+02	9.74E+01	3.60E+02	1.37E+02	3.27E-05	1.28E+00	2.76E+02	1.05E+00	1.05E+00
1.15E+03	6.00E-03	4.22E+01	2.17E+02	1.02E+02	4.18E+02	1.40E+02	2.08E-05	1.28E+00	2.76E+02	1.10E+00	1.10E+00
1.46E+03	5.66E-03	5.24E+01	2.37E+02	1.06E+02	4.87E+02	1.42E+02	1.32E-05	1.28E+00	2.76E+02	1.14E+00	1.14E+00
1.86E+03	5.36E-03	6.48E+01	2.59E+02	1.11E+02	5.69E+02	1.43E+02	8.36E-06	1.28E+00	2.76E+02	1.19E+00	1.19E+00
2.36E+03	5.09E-03	7.96E+01	2.85E+02	1.16E+02	6.66E+02	1.45E+02	5.28E-06	1.28E+00	2.76E+02	1.23E+00	1.23E+00
2.99E+03	4.85E-03	9.75E+01	3.14E+02	1.21E+02	7.83E+02	1.46E+02	3.33E-06	1.28E+00	2.76E+02	1.27E+00	1.27E+00
3.77E+03	4.64E-03	1.19E+02	3.47E+02	1.25E+02	9.23E+02	1.47E+02	2.10E-06	1.28E+00	2.76E+02	1.31E+00	1.31E+00
4.76E+03	4.45E-03	1.44E+02	3.84E+02	1.30E+02	1.09E+03	1.48E+02	1.32E-06	1.28E+00	2.76E+02	1.35E+00	1.35E+00

6.00E+03	4.29E-03	1.74E+02	4.25E+02	1.34E+02	1.29E+03	1.49E+02	8.37E-07	1.28E+00	2.76E+02	1.39E+00	1.39E+00
7.54E+03	4.14E-03	2.08E+02	4.73E+02	1.38E+02	1.63E+03	1.49E+02	5.29E-07	1.28E+00	2.76E+02	1.42E+00	1.42E+00
9.45E+03	4.02E-03	2.48E+02	5.26E+02	1.42E+02	1.82E+03	1.50E+02	3.36E-07	1.28E+00	2.76E+02	1.46E+00	1.46E+00
1.18E+04	3.90E-03	2.95E+02	5.85E+02	1.46E+02	2.16E+03	1.50E+02	2.14E-07	1.28E+00	2.76E+02	1.49E+00	1.49E+00
1.48E+04	3.80E-03	3.47E+02	6.52E+02	1.49E+02	2.57E+03	1.50E+02	1.37E-07	1.28E+00	2.76E+02	1.52E+00	1.52E+00
1.85E+04	3.71E-03	4.05E+02	7.27E+02	1.53E+02	3.06E+03	1.51E+02	8.86E-08	1.28E+00	2.76E+02	1.55E+00	1.55E+00
2.30E+04	3.64E-03	4.69E+02	8.11E+02	1.66E+02	3.64E+03	1.51E+02	5.76E-08	1.28E+00	2.76E+02	1.57E+00	1.57E+00

1

X	CM	CMV	CMDA	CMW	CMWV	WC	VG	UG	W	V	VX
1.00E+00	1.00E+00	-1.00E+00	0.	0.	-1.00E+00	5.62E+00	0.	0.	-1.00E+00	-1.00E+00	0.
1.01E+00	5.26E-01	2.33E-01	4.74E-01	6.61E-04	2.60E-06	1.45E-12	0.	0.	5.84E-02	2.48E-02	0.
1.03E+00	5.25E-01	2.33E-01	4.74E-01	6.62E-04	2.60E-06	-3.45E-01	0.	0.	9.23E-04	2.48E-02	1.27E-01
1.06E+00	5.25E-01	2.33E-01	4.75E-01	6.63E-04	2.60E-06	-7.62E-01	0.	0.	9.59E-04	2.48E-02	1.27E-01
1.09E+00	5.24E-01	2.33E-01	4.75E-01	6.64E-04	2.60E-06	-1.27E+00	0.	0.	1.05E-03	2.47E-02	1.27E-01
1.13E+00	5.23E-01	2.33E-01	4.76E-01	6.65E-04	2.60E-06	-1.88E+00	0.	0.	1.28E-03	2.45E-02	1.27E-01
1.18E+00	5.22E-01	2.33E-01	4.77E-01	6.66E-04	2.59E-06	-2.62E+00	0.	0.	2.16E-03	2.42E-02	1.26E-01
1.24E+00	5.21E-01	2.33E-01	4.79E-01	6.68E-04	2.59E-06	-3.07E+00	3.66E+00	0.	3.08E-02	2.38E-02	1.24E-01
1.31E+00	5.17E-01	2.35E-01	4.82E-01	6.73E-04	2.60E-06	-1.46E+00	4.49E+00	0.	8.46E-02	2.01E-02	1.19E-01
1.39E+00	5.05E-01	2.38E-01	4.94E-01	6.89E-04	2.62E-06	-6.82E-01	4.76E+00	0.	1.90E-01	1.61E-02	1.13E-01
1.49E+00	4.71E-01	2.46E-01	5.28E-01	7.37E-04	2.63E-06	-3.44E-01	4.57E+00	0.	3.29E-01	1.33E-02	1.07E-01
1.62E+00	4.10E-01	2.59E-01	5.89E-01	8.23E-04	2.60E-06	-2.03E-01	3.98E+00	0.	4.37E-01	1.50E-02	1.02E-01
1.77E+00	3.41E-01	2.71E-01	6.58E-01	9.18E-04	2.56E-06	-1.23E-01	3.29E+00	0.	3.71E-01	1.79E-02	1.00E-01
1.96E+00	2.89E-01	2.80E-01	7.10E-01	9.91E-04	2.55E-06	-7.95E-02	2.79E+00	0.	2.84E-01	1.85E-02	1.00E-01
2.18E+00	2.48E-01	2.48E-01	7.51E-01	1.05E-03	1.35E-05	-5.36E-02	2.41E+00	0.	2.16E-01	1.95E-02	1.00E-01
2.46E+00	2.16E-01	2.16E-01	7.83E-01	1.09E-03	5.12E-05	-3.75E-02	2.12E+00	0.	1.73E-01	2.03E-02	1.01E-01
2.79E+00	1.89E-01	1.89E-01	8.10E-01	1.13E-03	1.32E-04	-2.67E-02	1.89E+00	0.	1.43E-01	2.09E-02	1.01E-01
3.20E+00	1.65E-01	1.65E-01	8.34E-01	1.16E-03	2.69E-04	-1.92E-02	1.69E+00	0.	1.21E-01	2.13E-02	1.02E-01
3.69E+00	1.44E-01	1.44E-01	8.55E-01	1.19E-03	4.59E-04	-1.40E-02	1.52E+00	0.	1.00E-01	2.09E-02	1.03E-01
4.29E+00	1.26E-01	1.26E-01	8.72E-01	1.22E-03	6.89E-04	-1.02E-02	1.38E+00	0.	8.34E-02	1.98E-02	1.04E-01
5.02E+00	1.11E-01	1.11E-01	8.88E-01	1.24E-03	9.44E-04	-7.52E-03	1.27E+00	0.	7.04E-02	1.86E-02	1.05E-01
5.90E+00	9.67E-02	9.67E-02	9.02E-01	1.26E-03	1.21E-03	-5.53E-03	1.17E+00	0.	6.02E-02	1.74E-02	1.06E-01
6.97E+00	8.43E-02	8.43E-02	9.14E-01	1.28E-03	1.28E-03	-4.05E-03	1.08E+00	0.	5.15E-02	1.61E-02	1.07E-01
8.28E+00	7.33E-02	7.33E-02	9.25E-01	1.29E-03	1.29E-03	-2.95E-03	1.00E+00	0.	4.41E-02	1.50E-02	1.08E-01
9.87E+00	6.35E-02	6.35E-02	9.35E-01	1.31E-03	1.31E-03	-2.14E-03	9.38E-01	0.	3.80E-02	1.41E-02	1.09E-01
1.18E+01	5.47E-02	5.47E-02	9.44E-01	1.32E-03	1.32E-03	-1.63E-03	8.76E-01	0.	3.30E-02	1.36E-02	1.10E-01
1.41E+01	4.67E-02	4.67E-02	9.52E-01	1.33E-03	1.33E-03	-1.08E-03	8.11E-01	0.	3.09E-02	1.35E-02	1.10E-01
1.70E+01	3.92E-02	3.92E-02	9.59E-01	1.34E-03	1.34E-03	-7.58E-04	7.37E-01	0.	2.84E-02	1.34E-02	1.11E-01
2.04E+01	3.25E-02	3.25E-02	9.66E-01	1.35E-03	1.35E-03	-5.29E-04	6.62E-01	0.	2.62E-02	1.35E-02	1.12E-01
2.46E+01	2.67E-02	2.67E-02	9.72E-01	1.36E-03	1.36E-03	-3.71E-04	5.90E-01	0.	2.43E-02	1.35E-02	1.13E-01
2.98E+01	2.18E-02	2.18E-02	9.77E-01	1.36E-03	1.36E-03	-2.62E-04	5.22E-01	0.	2.29E-02	1.36E-02	1.14E-01
3.60E+01	1.76E-02	1.76E-02	9.81E-01	1.37E-03	1.37E-03	-1.87E-04	4.61E-01	0.	2.17E-02	1.38E-02	1.15E-01
4.35E+01	1.41E-02	1.41E-02	9.85E-01	1.37E-03	1.37E-03	-1.35E-04	4.06E-01	0.	2.09E-02	1.39E-02	1.16E-01
5.27E+01	1.12E-02	1.12E-02	9.87E-01	1.38E-03	1.38E-03	-9.82E-05	3.57E-01	0.	2.04E-02	1.41E-02	1.18E-01
6.38E+01	8.80E-03	8.80E-03	9.90E-01	1.38E-03	1.38E-03	-7.23E-05	3.14E-01	0.	2.01E-02	1.44E-02	1.19E-01
7.74E+01	6.87E-03	6.87E-03	9.92E-01	1.38E-03	1.38E-03	-5.38E-05	2.76E-01	0.	2.00E-02	1.46E-02	1.21E-01
9.38E+01	5.32E-03	5.32E-03	9.93E-01	1.39E-03	1.39E-03	-4.04E-05	2.44E-01	2.60E-01	2.01E-02	1.49E-02	1.22E-01
1.14E+02	3.75E-03	3.75E-03	9.95E-01	1.39E-03	1.39E-03	-5.40E-05	1.98E-01	2.10E-01	2.15E-02	1.52E-02	1.22E-01
1.40E+02	2.55E-03	2.55E-03	9.96E-01	1.39E-03	1.39E-03	-3.38E-05	1.59E-01	1.65E-01	2.26E-02	1.56E-02	1.24E-01
1.74E+02	1.70E-03	1.70E-03	9.97E-01	1.39E-03	1.39E-03	-2.17E-05	1.27E-01	1.29E-01	2.35E-02	1.62E-02	1.25E-01
2.17E+02	1.12E-03	1.12E-03	9.97E-01	1.39E-03	1.39E-03	-1.43E-05	1.04E-01	1.02E-01	2.42E-02	1.69E-02	1.26E-01
2.73E+02	7.28E-04	7.28E-04	9.98E-01	1.39E-03	1.39E-03	-9.75E-06	8.64E-02	8.13E-02	2.49E-02	1.76E-02	1.27E-01
3.45E+02	4.72E-04	4.72E-04	9.98E-01	1.39E-03	1.39E-03	-6.82E-06	7.34E-02	6.56E-02	2.55E-02	1.82E-02	1.28E-01
4.38E+02	3.05E-04	3.05E-04	9.98E-01	1.39E-03	1.39E-03	-4.88E-06	6.35E-02	5.35E-02	2.60E-02	1.88E-02	1.28E-01
5.58E+02	1.96E-04	1.96E-04	9.98E-01	1.39E-03	1.39E-03	-3.54E-06	5.55E-02	4.40E-02	2.64E-02	1.93E-02	1.29E-01
7.10E+02	1.26E-04	1.26E-04	9.98E-01	1.39E-03	1.39E-03	-2.59E-06	4.89E-02	3.63E-02	2.66E-02	1.97E-02	1.29E-01
9.04E+02	8.02E-05	8.02E-05	9.99E-01	1.39E-03	1.39E-03	-1.91E-06	4.32E-02	3.00E-02	2.68E-02	2.00E-02	1.29E-01
1.15E+03	5.10E-05	5.10E-05	9.99E-01	1.39E-03	1.39E-03	-1.41E-06	3.81E-02	2.48E-02	2.67E-02	2.01E-02	1.29E-01
1.46E+03	3.24E-05	3.24E-05	9.99E-01	1.39E-03	1.39E-03	-1.04E-06	3.34E-02	2.04E-02	2.66E-02	2.02E-02	1.29E-01
1.86E+03	2.05E-05	2.05E-05	9.99E-01	1.39E-03	1.39E-03	-7.62E-07	2.92E-02	1.67E-02	2.62E-02	2.01E-02	1.28E-01
2.36E+03	1.29E-05	1.29E-05	9.99E-01	1.39E-03	1.39E-03	-5.58E-07	2.54E-02	1.36E-02	2.57E-02	1.99E-02	1.28E-01
2.99E+03	8.16E-06	8.16E-06	9.99E-01	1.39E-03	1.39E-03	-4.07E-07	2.19E-02	1.10E-02	2.51E-02	1.96E-02	1.27E-01
3.77E+03	5.15E-06	5.15E-06	9.99E-01	1.39E-03	1.39E-03	-2.97E-07	1.88E-02	8.89E-03	2.43E-02	1.91E-02	1.26E-01
4.76E+03	3.25E-06	3.25E-06	9.99E-01	1.39E-03	1.39E-03	-2.16E-07	1.61E-02	7.13E-03	2.34E-02	1.86E-02	1.26E-01
6.00E+03	2.05E-06	2.05E-06	9.99E-01	1.39E-03	1.39E-03	-1.56E-07	1.36E-02	5.69E-03	2.23E-02	1.80E-02	1.24E-01
7.54E+03	1.30E-06	1.30E-06	9.99E-01	1.39E-03	1.39E-03	-1.13E-07	1.15E-02	4.53E-03	2.12E-02	1.73E-02	1.23E-01
9.45E+03	8.23E-07	8.23E-07	9.99E-01	1.39E-03	1.39E-03	-8.22E-08	9.72E-03	3.59E-03	1.99E-02	1.65E-02	1.22E-01

1.18E+04	5.25E-07	5.25E-07	9.99E-01	1.39E-03	1.39E-03	-6.97E-08	8.18E-03	2.84E-03	1.85E-02	1.57E-02	1.20E-01
1.48E+04	3.36E-07	3.36E-07	9.99E-01	1.39E-03	1.39E-03	-4.34E-08	6.88E-03	2.25E-03	1.71E-02	1.49E-02	1.18E-01
1.85E+04	2.17E-07	2.17E-07	9.99E-01	1.39E-03	1.39E-03	-3.17E-08	5.78E-03	1.78E-03	1.65E-02	1.41E-02	1.16E-01
2.30E+04	1.41E-07	1.41E-07	9.99E-01	1.39E-03	1.39E-03	-2.32E-08	4.87E-03	1.41E-03	1.38E-02	1.32E-02	1.14E-01

1

TIME AVERAGED (TAV =   1. S) VOLUME CONCENTRATION: CONCENTRATION CONTOUR PARAMETERS

```
C(X,Y,Z,T) = CC(X) * (ERF(XA)-ERF(XB)) * (ERF(YA)-ERF(YB)) * (EXP(-ZA*ZA)+EXP(-ZB*ZB))

   C(X,Y,Z,T) = CONCENTRATION (VOLUME FRACTION) AT (X,Y,Z,T)
            X = DOWNWIND DISTANCE (M)
            Y = CROSSWIND HORIZONTAL DISTANCE (M)
            Z = HEIGHT (M)
            T = TIME (S)

          ERF = ERROR FUNCTON
           XA = (X-XC+BX)/(SR2*BETAX)
           XB = (X-XC-BX)/(SR2*BETAX)
           YA = (Y+B)/(SR2*BETAC)
           YB = (Y-B)/(SR2*BETAC)
          EXP = EXPONENTIAL FUNCTION
           ZA = (Z-ZC)/(SR2*SIG)
           ZB = (Z+ZC)/(SR2*SIG)
          SR2 = SQRT(2.0)
```

X	CC(X)	B(X)	BETAC(X)	ZC(X)	SIG(X)
1.00E+00	0.	6.36E-02	1.78E-02	1.00E+00	4.08E-02
1.01E+00	1.65E-01	7.90E-01	5.29E-01	2.24E+00	6.99E-01
1.03E+00	1.65E-01	7.90E-01	5.31E-01	2.23E+00	6.99E-01
1.06E+00	1.65E-01	7.91E-01	5.32E-01	2.19E+00	6.99E-01
1.09E+00	1.65E-01	7.91E-01	5.33E-01	2.10E+00	7.01E-01
1.13E+00	1.65E-01	7.92E-01	5.35E-01	1.92E+00	7.03E-01
1.18E+00	1.65E-01	7.92E-01	5.39E-01	1.62E+00	7.08E-01
1.24E+00	1.62E-01	8.59E-01	5.90E-01	1.12E+00	6.74E-01
1.31E+00	1.64E-01	1.38E+00	9.52E-01	6.97E-01	4.02E-01
1.39E+00	1.58E-01	2.08E+00	1.43E+00	4.64E-01	2.68E-01
1.49E+00	1.44E-01	2.87E+00	1.98E+00	3.36E-01	1.94E-01
1.62E+00	1.19E-01	3.37E+00	2.33E+00	2.68E-01	1.55E-01
1.77E+00	8.08E-02	3.93E+00	2.73E+00	2.30E-01	1.85E-01
1.96E+00	5.76E-02	4.51E+00	3.13E+00	2.01E-01	2.33E-01
2.18E+00	4.34E-02	5.11E+00	3.55E+00	1.78E-01	2.92E-01
2.46E+00	3.47E-02	5.75E+00	4.00E+00	1.59E-01	3.42E-01
2.79E+00	2.85E-02	6.43E+00	4.49E+00	1.42E-01	3.87E-01
3.20E+00	2.38E-02	7.16E+00	5.01E+00	1.28E-01	4.30E-01
3.69E+00	1.99E-02	7.97E+00	5.59E+00	1.15E-01	4.79E-01
4.29E+00	1.69E-02	8.87E+00	6.25E+00	1.04E-01	5.33E-01
5.02E+00	1.44E-02	9.90E+00	7.00E+00	9.31E-02	5.87E-01
5.90E+00	1.23E-02	1.11E+01	7.87E+00	8.33E-02	6.42E-01
6.97E+00	1.06E-02	1.25E+01	8.89E+00	7.42E-02	7.00E-01
8.28E+00	9.04E-03	1.41E+01	1.01E+01	6.58E-02	7.63E-01
9.87E+00	7.73E-03	1.60E+01	1.15E+01	5.81E-02	8.28E-01
1.18E+01	6.60E-03	1.82E+01	1.32E+01	5.10E-02	8.93E-01
1.41E+01	5.60E-03	2.08E+01	1.51E+01	4.47E-02	9.34E-01
1.70E+01	4.67E-03	2.36E+01	1.73E+01	3.93E-02	9.89E-01
2.04E+01	3.87E-03	2.68E+01	1.97E+01	3.47E-02	1.05E+00
2.46E+01	3.17E-03	3.01E+01	2.23E+01	3.09E-02	1.13E+00
2.98E+01	2.58E-03	3.36E+01	2.51E+01	2.76E-02	1.22E+00
3.60E+01	2.08E-03	3.73E+01	2.81E+01	2.49E-02	1.33E+00
4.35E+01	1.67E-03	4.11E+01	3.13E+01	2.26E-02	1.46E+00
5.27E+01	1.33E-03	4.50E+01	3.46E+01	2.06E-02	1.63E+00
6.38E+01	1.05E-03	4.91E+01	3.80E+01	1.89E-02	1.83E+00
7.74E+01	8.23E-04	5.32E+01	4.17E+01	1.74E-02	2.07E+00
9.38E+01	6.41E-04	5.74E+01	4.55E+01	1.62E-02	2.36E+00

T	XC(T)	BX(T)	BETAX(T)
0.	1.00E+00	0.	0.
6.22E-02	1.01E+00	1.10E-02	8.96E-05
1.84E-01	1.03E+00	3.24E-02	2.65E-04
3.32E-01	1.06E+00	5.85E-02	4.78E-04
5.12E-01	1.09E+00	9.02E-02	7.37E-04
7.31E-01	1.13E+00	1.29E-01	1.05E-03
9.99E-01	1.18E+00	1.76E-01	1.43E-03
1.33E+00	1.24E+00	2.33E-01	1.90E-03
1.72E+00	1.31E+00	3.02E-01	2.46E-03
2.18E+00	1.39E+00	3.86E-01	3.15E-03
2.70E+00	1.49E+00	4.88E-01	3.98E-03
3.21E+00	1.62E+00	6.12E-01	5.00E-03
3.70E+00	1.77E+00	7.63E-01	6.23E-03
4.28E+00	1.96E+00	9.46E-01	7.73E-03
4.98E+00	2.18E+00	1.17E+00	9.54E-03
5.84E+00	2.46E+00	1.44E+00	1.18E-02
6.89E+00	2.79E+00	1.77E+00	1.44E-02
8.16E+00	3.20E+00	2.17E+00	1.77E-02
9.72E+00	3.69E+00	2.65E+00	2.17E-02
1.17E+01	4.29E+00	3.24E+00	2.65E-02
1.41E+01	5.02E+00	3.96E+00	3.24E-02
1.71E+01	5.90E+00	4.83E+00	3.95E-02
2.10E+01	6.97E+00	5.89E+00	4.81E-02
2.58E+01	8.28E+00	7.18E+00	5.86E-02
3.20E+01	9.87E+00	8.75E+00	7.14E-02
3.99E+01	1.18E+01	1.06E+01	8.69E-02
4.97E+01	1.41E+01	1.30E+01	1.06E-01
6.16E+01	1.70E+01	1.58E+01	1.29E-01
7.60E+01	2.04E+01	1.92E+01	1.57E-01
9.34E+01	2.46E+01	2.33E+01	1.90E-01
1.14E+02	2.98E+01	2.84E+01	2.32E-01
1.39E+02	3.60E+01	3.45E+01	2.82E-01
1.68E+02	4.35E+01	4.19E+01	3.42E-01
2.02E+02	5.27E+01	5.10E+01	4.16E-01
2.42E+02	6.38E+01	6.20E+01	5.06E-01
2.90E+02	7.74E+01	7.53E+01	6.15E-01
3.45E+02	9.38E+01	9.16E+01	7.48E-01

1.14E+02	4.88E-04	6.17E+01	4.95E+01	1.40E-02	2.67E+00
1.40E+02	3.61E-04	6.58E+01	5.35E+01	1.23E-02	3.17E+00
1.74E+02	2.63E-04	6.97E+01	5.77E+01	1.10E-02	3.90E+00
2.17E+02	1.90E-04	7.35E+01	6.21E+01	9.96E-03	4.87E+00
2.73E+02	1.38E-04	7.73E+01	6.68E+01	9.12E-03	6.14E+00
3.46E+02	1.01E-04	8.11E+01	7.20E+01	8.41E-03	7.77E+00
4.38E+02	7.39E-05	8.50E+01	7.78E+01	7.80E-03	9.83E+00
5.58E+02	5.46E-05	8.90E+01	8.44E+01	7.27E-03	1.24E+01
7.10E+02	4.06E-05	9.31E+01	9.20E+01	6.80E-03	1.56E+01
9.04E+02	3.04E-05	9.74E+01	1.01E+02	6.38E-03	1.96E+01
1.15E+03	2.29E-05	1.02E+02	1.11E+02	6.00E-03	2.44E+01
1.46E+03	1.74E-05	1.06E+02	1.22E+02	5.66E-03	3.03E+01
1.86E+03	1.34E-05	1.11E+02	1.35E+02	5.36E-03	3.74E+01
2.36E+03	1.03E-05	1.16E+02	1.50E+02	5.09E-03	4.60E+01
2.99E+03	8.03E-06	1.21E+02	1.67E+02	4.85E-03	5.63E+01
3.77E+03	6.30E-06	1.26E+02	1.87E+02	4.64E-03	6.86E+01
4.76E+03	4.99E-06	1.30E+02	2.08E+02	4.46E-03	8.31E+01
6.00E+03	3.98E-06	1.34E+02	2.33E+02	4.29E-03	1.00E+02
7.54E+03	3.21E-06	1.38E+02	2.61E+02	4.14E-03	1.20E+02
9.45E+03	2.61E-06	1.42E+02	2.92E+02	4.02E-03	1.43E+02
1.18E+04	2.14E-06	1.46E+02	3.27E+02	3.90E-03	1.70E+02
1.48E+04	1.77E-06	1.49E+02	3.66E+02	3.80E-03	2.00E+02
1.85E+04	1.48E-06	1.53E+02	4.10E+02	3.71E-03	2.34E+02
2.30E+04	1.25E-06	1.56E+02	4.59E+02	3.64E-03	2.71E+02

3.33E+02	1.14E+02	9.90E+01	2.21E+01
3.73E+02	1.40E+02	1.06E+02	3.52E+01
4.21E+02	1.74E+02	1.12E+02	4.84E+01
4.80E+02	2.17E+02	1.17E+02	6.23E+01
5.51E+02	2.73E+02	1.21E+02	7.77E+01
6.38E+02	3.46E+02	1.25E+02	9.49E+01
7.43E+02	4.38E+02	1.29E+02	1.14E+02
8.72E+02	5.58E+02	1.32E+02	1.37E+02
1.03E+03	7.10E+02	1.35E+02	1.62E+02
1.22E+03	9.04E+02	1.37E+02	1.92E+02
1.45E+03	1.15E+03	1.40E+02	2.28E+02
1.73E+03	1.46E+03	1.42E+02	2.69E+02
2.07E+03	1.86E+03	1.43E+02	3.18E+02
2.48E+03	2.36E+03	1.45E+02	3.75E+02
2.98E+03	2.99E+03	1.46E+02	4.44E+02
3.59E+03	3.77E+03	1.47E+02	5.26E+02
4.33E+03	4.76E+03	1.48E+02	6.24E+02
5.23E+03	6.00E+03	1.49E+02	7.40E+02
6.33E+03	7.54E+03	1.49E+02	8.80E+02
7.66E+03	9.45E+03	1.50E+02	1.05E+03
9.27E+03	1.18E+04	1.50E+02	1.24E+03
1.12E+04	1.48E+04	1.50E+02	1.48E+03
1.36E+04	1.85E+04	1.51E+02	1.76E+03
1.65E+04	2.30E+04	1.51E+02	2.10E+03

1

00

TIME AVERAGED (TAV = 1. S) VOLUME CONCENTRATION: CONCENTRATION IN THE Z = 1.00 PLANE.

DOWNWIND DISTANCE X (M)	TIME OF MAX CONC (S)	CLOUD DURATION (S)	EFFECTIVE HALF WIDTH BBC (M)	AVERAGE CONCENTRATION (VOLUME FRACTION) AT (X,Y,Z) Y/BBC= 0.0	Y/BBC= 0.5	Y/BBC= 1.0	Y/BBC= 1.5	Y/BBC= 2.0	Y/BBC= 2.5
1.00E+00	1.50E+02	3.00E+02	7.07E-02	1.00E+00	1.00E+00	5.31E-01	1.31E-02	9.50E-06	1.57E-10
1.01E+00	1.50E+02	3.00E+02	1.21E+00	1.18E-01	8.66E-02	2.92E-02	3.61E-03	1.42E-04	1.65E-06
1.03E+00	1.50E+02	3.00E+02	1.21E+00	1.21E-01	8.88E-02	3.00E-02	3.71E-03	1.46E-04	1.71E-06
1.06E+00	1.50E+02	3.00E+02	1.21E+00	1.35E-01	9.83E-02	3.32E-02	4.11E-03	1.62E-04	1.91E-06
1.09E+00	1.50E+02	3.00E+02	1.22E+00	1.67E-01	1.22E-01	4.12E-02	5.11E-03	2.02E-04	2.39E-06
1.13E+00	1.50E+02	3.00E+02	1.22E+00	2.39E-01	1.75E-01	5.90E-02	7.33E-03	2.92E-04	3.48E-06
1.18E+00	1.50E+02	3.00E+02	1.23E+00	3.85E-01	2.80E-01	9.46E-02	1.18E-02	4.75E-04	5.76E-06
1.24E+00	1.50E+02	3.00E+02	1.33E+00	5.47E-01	3.99E-01	1.34E-01	1.68E-02	6.86E-04	8.51E-06
1.31E+00	1.50E+02	3.00E+02	2.15E+00	4.21E-01	3.06E-01	1.03E-01	1.30E-02	5.31E-04	6.63E-06
1.39E+00	1.51E+02	3.00E+02	3.24E+00	7.25E-02	5.28E-02	1.78E-02	2.24E-03	9.18E-05	1.15E-06
1.49E+00	1.51E+02	3.00E+02	4.47E+00	1.43E-03	1.04E-03	3.51E-04	4.42E-05	1.82E-06	2.29E-08
1.62E+00	1.51E+02	3.00E+02	5.26E+00	5.89E-06	4.29E-06	1.44E-06	1.82E-07	7.49E-09	9.46E-11
1.77E+00	1.51E+02	3.00E+02	6.15E+00	4.76E-05	3.46E-05	1.17E-05	1.47E-06	6.07E-08	7.69E-10
1.96E+00	1.52E+02	3.00E+02	7.05E+00	5.61E-04	4.08E-04	1.37E-04	1.73E-05	7.17E-07	9.11E-09
2.18E+00	1.52E+02	3.00E+02	7.99E+00	2.85E-03	2.07E-03	6.98E-04	8.81E-05	3.65E-06	4.66E-08
2.46E+00	1.52E+02	3.00E+02	9.00E+00	6.14E-03	4.46E-03	1.50E-03	1.90E-04	7.90E-06	1.01E-07
2.79E+00	1.53E+02	3.00E+02	1.01E+01	9.59E-03	6.96E-03	2.34E-03	2.97E-04	1.24E-05	1.60E-07
3.20E+00	1.54E+02	3.00E+02	1.13E+01	1.28E-02	9.32E-03	3.14E-03	3.98E-04	1.67E-05	2.17E-07
3.69E+00	1.54E+02	3.00E+02	1.25E+01	1.68E-02	1.22E-02	4.10E-03	5.20E-04	2.19E-05	2.87E-07
4.29E+00	1.55E+02	3.00E+02	1.40E+01	2.06E-02	1.50E-02	5.03E-03	6.40E-04	2.71E-05	3.58E-07
5.02E+00	1.56E+02	3.00E+02	1.57E+01	2.33E-02	1.69E-02	5.69E-03	7.26E-04	3.09E-05	4.12E-07
5.90E+00	1.58E+02	3.00E+02	1.76E+01	2.49E-02	1.81E-02	6.07E-03	7.76E-04	3.32E-05	4.48E-07
6.97E+00	1.60E+02	3.00E+02	1.98E+01	2.57E-02	1.86E-02	6.25E-03	8.01E-04	3.45E-05	4.70E-07
8.28E+00	1.62E+02	3.00E+02	2.24E+01	2.57E-02	1.86E-02	6.24E-03	8.02E-04	3.48E-05	4.78E-07
9.87E+00	1.64E+02	3.00E+02	2.55E+01	2.49E-02	1.80E-02	6.05E-03	7.80E-04	3.40E-05	4.73E-07
1.18E+01	1.67E+02	3.00E+02	2.92E+01	2.35E-02	1.70E-02	5.70E-03	7.37E-04	3.24E-05	4.56E-07
1.41E+01	1.71E+02	3.00E+02	3.34E+01	2.10E-02	1.51E-02	5.08E-03	6.58E-04	2.91E-05	4.15E-07
1.70E+01	1.76E+02	3.00E+02	3.82E+01	1.86E-02	1.34E-02	4.49E-03	5.83E-04	2.60E-05	3.76E-07
2.04E+01	1.81E+02	3.00E+02	4.34E+01	1.62E-02	1.17E-02	3.92E-03	5.11E-04	2.30E-05	3.37E-07
2.46E+01	1.88E+02	3.00E+02	4.90E+01	1.41E-02	1.01E-02	3.39E-03	4.44E-04	2.02E-05	3.00E-07
2.98E+01	1.96E+02	3.00E+02	5.50E+01	1.21E-02	8.68E-03	2.91E-03	3.82E-04	1.75E-05	2.64E-07
3.60E+01	2.07E+02	3.00E+02	6.13E+01	1.02E-02	7.35E-03	2.46E-03	3.24E-04	1.50E-05	2.30E-07
4.35E+01	2.19E+02	3.00E+02	6.80E+01	8.69E-03	6.16E-03	2.06E-03	2.73E-04	1.28E-05	1.99E-07
5.27E+01	2.34E+02	3.00E+02	7.49E+01	7.11E-03	5.09E-03	1.70E-03	2.26E-04	1.07E-05	1.70E-07
6.38E+01	2.52E+02	3.00E+02	8.21E+01	5.80E-03	4.15E-03	1.39E-03	1.85E-04	8.85E-06	1.43E-07
7.74E+01	2.73E+02	3.00E+02	8.97E+01	4.68E-03	3.34E-03	1.12E-03	1.50E-04	7.24E-06	1.20E-07
9.38E+01	3.00E+02	3.00E+02	9.75E+01	3.72E-03	2.65E-03	8.85E-04	1.19E-04	5.84E-06	9.86E-08
1.14E+02	3.33E+02	3.33E+02	1.06E+02	2.87E-03	2.04E-03	6.81E-04	9.21E-05	4.58E-06	7.91E-08
1.40E+02	3.73E+02	3.63E+02	1.14E+02	2.14E-03	1.52E-03	5.07E-04	6.90E-05	3.48E-06	6.16E-08
1.74E+02	4.21E+02	3.91E+02	1.22E+02	1.54E-03	1.09E-03	3.63E-04	4.98E-05	2.55E-06	4.65E-08
2.17E+02	4.80E+02	4.19E+02	1.30E+02	1.07E-03	7.57E-04	2.52E-04	3.47E-05	1.82E-06	3.42E-08
2.73E+02	5.51E+02	4.49E+02	1.39E+02	7.24E-04	5.11E-04	1.70E-04	2.36E-05	1.26E-06	2.46E-08
3.45E+02	6.38E+02	4.83E+02	1.49E+02	4.81E-04	3.39E-04	1.12E-04	1.58E-05	8.61E-07	1.76E-08
4.38E+02	7.43E+02	5.22E+02	1.59E+02	3.16E-04	2.22E-04	7.35E-05	1.04E-05	5.82E-07	1.23E-08
5.58E+02	8.72E+02	5.68E+02	1.71E+02	2.05E-04	1.44E-04	4.76E-05	6.79E-06	3.90E-07	8.62E-09
7.10E+02	1.03E+03	6.23E+02	1.85E+02	1.33E-04	9.27E-05	3.06E-05	4.40E-06	2.60E-07	6.01E-09
9.04E+02	1.22E+03	6.87E+02	2.00E+02	8.60E-05	5.93E-05	1.95E-05	2.84E-06	1.72E-07	4.17E-09
1.15E+03	1.45E+03	7.63E+02	2.17E+02	5.43E-05	3.78E-05	1.24E-05	1.82E-06	1.13E-07	2.87E-09
1:46E+03	1.73E+03	8.53E+02	2.37E+02	3.45E-05	2.40E-05	7.87E-06	1.16E-06	7.40E-08	1.96E-09
1.86E+03	2.07E+03	9.59E+02	2.59E+02	2.19E-05	1.52E-05	4.97E-06	7.40E-07	4.81E-08	1.33E-09
2.36E+03	2.48E+03	1.08E+03	2.85E+02	1.39E-05	9.59E-06	3.13E-06	4.69E-07	3.12E-08	8.95E-10
2.99E+03	2.98E+03	1.23E+03	3.14E+02	8.76E-06	6.05E-06	1.97E-06	2.97E-07	2.01E-08	5.96E-10

3.77E+03	3.59E+03	1.41E+03	3.47E+02	5.53E-06	3.81E-06	1.24E-06	1.88E-07	1.29E-08	3.94E-10
4.76E+03	4.33E+03	1.61E+03	3.84E+02	3.49E-06	2.40E-06	7.83E-07	1.19E-07	8.26E-09	2.59E-10
6.00E+03	5.23E+03	1.86E+03	4.25E+02	2.20E-06	1.62E-06	4.94E-07	7.52E-08	5.28E-09	1.69E-10
7.64E+03	6.33E+03	2.15E+03	4.73E+02	1.40E-06	9.61E-07	3.12E-07	4.76E-08	3.37E-09	1.10E-10
9.46E+03	7.66E+03	2.49E+03	5.26E+02	8.86E-07	6.10E-07	1.98E-07	3.03E-08	2.16E-09	7.09E-11
1.18E+04	9.27E+03	2.90E+03	5.86E+02	5.65E-07	3.89E-07	1.26E-07	1.93E-08	1.38E-09	4.59E-11
1.48E+04	1.12E+04	3.38E+03	6.52E+02	3.62E-07	2.49E-07	8.09E-08	1.24E-08	8.89E-10	2.98E-11
1.85E+04	1.36E+04	3.95E+03	7.27E+02	2.34E-07	1.61E-07	5.22E-08	7.99E-09	5.76E-10	1.94E-11
2.30E+04	1.65E+04	4.63E+03	8.11E+02	1.52E-07	1.05E-07	3.40E-08	5.20E-09	3.75E-10	1.27E-11

1

TIME AVERAGED (TAV = 1. S) VOLUME CONCENTRATION: MAXIMUM CONCENTRATION (VOLUME FRACTION) ALONG CENTERLINE.

DOWNWIND DISTANCE X (M)	HEIGHT Z (M)	MAXIMUM CONCENTRATION C(X,0,Z)	TIME OF MAX CONC (S)	CLOUD DURATION (S)
1.00E+00	1.00E+00	1.00E+00	1.50E+02	3.00E+02
1.01E+00	2.24E+00	5.70E-01	1.50E+02	3.00E+02
1.03E+00	2.23E+00	5.69E-01	1.50E+02	3.00E+02
1.06E+00	2.19E+00	5.69E-01	1.50E+02	3.00E+02
1.09E+00	2.10E+00	5.68E-01	1.50E+02	3.00E+02
1.13E+00	1.92E+00	5.66E-01	1.50E+02	3.00E+02
1.18E+00	1.62E+00	5.65E-01	1.50E+02	3.00E+02
1.24E+00	1.11E+00	5.54E-01	1.50E+02	3.00E+02
1.31E+00	6.93E-01	5.60E-01	1.50E+02	3.00E+02
1.39E+00	4.61E-01	5.42E-01	1.51E+02	3.00E+02
1.49E+00	3.35E-01	4.91E-01	1.51E+02	3.00E+02
1.62E+00	2.67E-01	4.07E-01	1.51E+02	3.00E+02
1.77E+00	2.01E-01	2.90E-01	1.51E+02	3.00E+02
1.96E+00	0.	2.70E-01	1.52E+02	3.00E+02
2.18E+00	0.	2.45E-01	1.52E+02	3.00E+02
2.46E+00	0.	2.12E-01	1.52E+02	3.00E+02
2.79E+00	0.	1.81E-01	1.53E+02	3.00E+02
3.20E+00	0.	1.54E-01	1.54E+02	3.00E+02
3.69E+00	0.	1.31E-01	1.54E+02	3.00E+02
4.29E+00	0.	1.12E-01	1.55E+02	3.00E+02
5.02E+00	0.	9.59E-02	1.56E+02	3.00E+02
5.90E+00	0.	8.22E-02	1.58E+02	3.00E+02
6.97E+00	0.	7.04E-02	1.60E+02	3.00E+02
8.28E+00	0.	6.03E-02	1.62E+02	3.00E+02
9.87E+00	0.	5.15E-02	1.64E+02	3.00E+02
1.18E+01	0.	4.39E-02	1.67E+02	3.00E+02
1.41E+01	0.	3.71E-02	1.71E+02	3.00E+02
1.70E+01	0.	3.09E-02	1.76E+02	3.00E+02
2.04E+01	0.	2.55E-02	1.81E+02	3.00E+02
2.46E+01	0.	2.08E-02	1.88E+02	3.00E+02
2.98E+01	0.	1.69E-02	1.96E+02	3.00E+02
3.60E+01	0.	1.36E-02	2.07E+02	3.00E+02
4.35E+01	0.	1.08E-02	2.19E+02	3.00E+02
5.27E+01	0.	8.58E-03	2.34E+02	3.00E+02
6.38E+01	0.	6.74E-03	2.52E+02	3.00E+02
7.74E+01	0.	5.26E-03	2.73E+02	3.00E+02
9.38E+01	0.	4.07E-03	3.00E+02	3.00E+02
1.14E+02	0.	3.07E-03	3.33E+02	3.33E+02
1.40E+02	0.	2.25E-03	3.73E+02	3.63E+02
1.74E+02	0.	1.59E-03	4.21E+02	3.91E+02
2.17E+02	0.	1.09E-03	4.80E+02	4.19E+02
2.73E+02	0.	7.33E-04	5.51E+02	4.49E+02
3.45E+02	0.	4.85E-04	6.38E+02	4.83E+02
4.38E+02	0.	3.17E-04	7.43E+02	5.22E+02
5.58E+02	0.	2.06E-04	8.72E+02	5.68E+02
7.10E+02	0.	1.33E-04	1.03E+03	6.23E+02
9.04E+02	0.	8.51E-05	1.22E+03	6.87E+02
1.15E+03	0.	5.44E-05	1.45E+03	7.63E+02
1.46E+03	0.	3.46E-05	1.73E+03	8.53E+02
1.86E+03	0.	2.19E-05	2.07E+03	9.59E+02
2.36E+03	0.	1.39E-05	2.48E+03	1.08E+03
2.99E+03	0.	8.76E-06	2.98E+03	1.23E+03

3.77E+03	0.	5.53E-06	3.59E+03	1.41E+03
4.76E+03	0.	3.49E-06	4.33E+03	1.61E+03
6.00E+03	0.	2.20E-06	5.23E+03	1.86E+03
7.54E+03	0.	1.40E-06	6.33E+03	2.15E+03
9.45E+03	0.	8.86E-07	7.66E+03	2.49E+03
1.18E+04	0.	5.65E-07	9.27E+03	2.90E+03
1.48E+04	0.	3.62E-07	1.12E+04	3.38E+03
1.85E+04	0.	2.34E-07	1.36E+04	3.95E+03
2.30E+04	0.	1.52E-07	1.65E+04	4.63E+03

5. REFERENCES

Bakke, P. (1957), "An Experimental Investigation of a Wall Jet," *J. Fluid Mech., 2,* 467–472.

Blewitt, D.N., J.F. Yohn, and D. L. Ermak (1987a), "An Evaluation of SLAB and DEGADIS Heavy Gas Dispersion Models Using the HF Spill Test Data," in *Proceedings of the AIChE International Conference on Vapor Cloud Modeling,* Boston, Mass., November 2–4.

Blewitt, D. N., J.F. Yohn, R.P. Koopman, and T.C. Brown (1987b), "Conduct of Anhydrous Hydrofluoric Acid Spill Experiments," in *Proceedings of the AIChE International Conference on Vapor Cloud Modeling,* Boston, Mass., November 2–4.

Braker, W. and A.L. Mossman (1980), *Matheson Gas Data Book,* 6th Ed., Matheson, Division Searle Medical Products U.S.A. Inc., Lyndhurst, NJ.

Briggs, G.A. (1984), "Plume Rise and Buoyancy Effects," in *Atmospheric Science and Power Production,* D. Randerson, Editor, DOE/TIC-27601, Office of Scientific and Technical Information, US Dept. of Energy.

Chatwin, P.C. (1968), "The Dispersion of a Puff of Passive Contaminant in the Constant Stress Region," *Q. J. Roy. Met. Soc., 94,* 350–360.

Clauser, F.H. (1954), "Turbulent Boundary Layers in Adverse Pressure Gradients," *J. Aeronaut. Sci., 21,* 91–108.

Deardorff, J.W. and G.E. Willis (1982), "Dependence of Mixed Layer Entrainment on Shear Stress and Velocity Jump," *J. Fluid Mech., 115,* 123–149.

Dyer, A.J. (1974), "A Review of Flux-Profile Relationships," *Boundary-Layer Meteor., 7,* 363–372, 1974.

Ellison, T.H. and S.J. Turner (1959), "Turbulent Entrainment in Stratified Flows," *J. Fluid Mech., 8,* 514–544.

Ermak, D.L. and S.T. Chan (1985), "A Study of Heavy Gas Effects on the Atmospheric Dispersion of Dense Gases," in *Air Pollution Modelling and Its Application V,* Plenum Press, 723–742.

Ermak, D.L. and S.T. Chan (1986), "Recent Developments on the FEM3 and SLAB Atmospheric Dispersion Models," in *Proceedings of the IMA Conference on Stably Stratified Flows and Dense-Gas Dispersion,* Chester, England.

Ermak, D.L., S.T. Chan, D.L. Morgan, and L.K. Morris (1982), "A Comparison of Dense Gas Dispersion Model Simulations with Burro Series LNG Spill Test Results," *J. of Haz. Materials, 6,* 129–160.

Gifford, F.A. (1976), "Turbulent Diffusion-Typing Schemes: A Review," *Nuclear Safety, 17* (1).

Golder, D. (1972), "Relations Among Stability Parameters in the Surface Layer," *Boundary-Layer Meteor., 3,* 47–58.

Goldwire, H.C. Jr., T.G. McRae, G.W. Johnson, D.L. Hipple, R.P. Koopman, J.W. McClure, L.K. Morris, and R.T. Cederwall (1985), "Desert Tortoise Series Data Report 1983 Pressurized Ammonia Spills," UCID-20562, Lawrence Livermore National Laboratory, Livermore, CA.

Hoot, T.G., R.N. Meroney, and J.A. Peterka (1973), "Wind Tunnel Tests of Negatively Buoyant Plumes," CER73-74GH-RNM-JAP-13, Colorado State University, Fort Collins, CO.

Kantha, L.H., O.M. Phillips, and R.S. Azad (1977), "On the Turbulent Entrainment at a Stable Density Interface," *J. Fluid Mechanics, 79,* 753–768.

Koopman, R.P., R.T. Cederwall, D.L. Ermak, H.C. Goldwire, Jr., W.J. Hogan, J.W. McClure, T.G. McRae, D.L. Morgan, H.C. Rodean, and J.H. Shinn (1982), "Analysis of Burro Series 40-m^3 LNG Spill Experiments," *J. Haz. Materials, 6,* 43–83.

Lilly, D.K. (1968), "Models of Cloud-Topped Mixed Layers Under a Strong Inversion," *Quart. J. Roy. Meteor. Soc., 94,* 292–309.

Lofquist, K. (1960), "Flow and Stress Near an Interface Between Stratified Liquids," *Physics of Fluids, 3* (2).

McQuaid, J. (1986), "Some Experiments on the Structure of Stably Stratified Shear Flows," Technical Paper P21, Safety in Mines Research Establishment, Sheffield, U.K.

Morgan, D.L. Jr., L.K. Morris, S.T. Chan, D.L. Ermak, T.G. McRae, R.T. Cederwall, R.P. Koopman, H.C Goldwire, Jr., J.W. McClure, and W.J. Hogan (1984), "Phenomenology and Modeling of Liquefied Natural Gas Vapor Dispersion," UCRL-53581, Lawrence Livermore National Laboratory, Livermore, CA.

Morgan, D.L., Jr., L.K. Morris, and D.L. Ermak (1983), "SLAB: A Time-Dependent Computer Model for the Dispersion of Heavy Gas Released in the Atmosphere," UCRL-53383, Lawrence Livermore National Laboratory, Livermore, CA.

Page, C.H. and P. Vigoureux (Eds.) (1972), *The International System of Units,* National Bureau of Standards Special Publication 330.

Pasquill, F. and F.B. Smith (1983), *Atmospheric Diffusion,* 3rd Ed., John Wiley and Sons, New York.

Petersen, W.B. (1982), "Estimating Concentrations Downwind from an Instantaneous Puff Release," EPA 600/3-82-078, US Environmental Protection Agency, Research Triangle Park, NC.

Reid, R.C., J.M. Prausnitz, and T.K. Sherwood (1977), *The Properties of Gases and Liquids,* 3rd Ed., McGraw-Hill Book Company, New York.

Slade, D.H. (Ed.), *Meteorology and Atomic Energy (1968),* U.S. Atomic Energy Commission, Office of Information Services.

Wilson, D.J. (1981), "Along-Wind Diffusion of Source Transients," *Atmos. Envir., 15,* 489–495.

Zeman, O. (1982), "The Dynamics and Modeling of Heavier-than-Air, Cold Gas Releases, *Atmos. Environ., 16,* 741–751.

ACKNOWLEDGMENT

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract W-7405-Eng-48. It was supported by the U.S. Department of Energy, the USAF Engineering and Services Center, and the American Petroleum Institute.

[tex.heavygas.report]SLAB-USERS-MANUAL-1.tex