United States
Environmental Protection
Agency

Office of Air Quality
Planning and Standards
Research Triangle Park NC 27711

EPA-450/4-91-007
March 1991

Air

EPA

GUIDANCE ON THE APPLICATION OF REFINED DISPERSION MODELS FOR AIR TOXICS RELEASES

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By

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March 1991

This report has been reviewed by the Office Of Air Quality Planning And Standards, U. S. Environmental Protection Agency, and has been approved for publication. Any mention of trade names or commercial products is not intended to constitute endorsement or recommendation for use.

EPA-450/4-91-007

Acknowledgements

This document was prepared by Jawad S. Touma, Source Receptor Analysis Branch, OAQPS. Through their reviews and numerous discussions, Dr. David Guinnup, U.S. EPA and Dr. Tom Spicer, University of Arkansas have contributed to numerous portions of the document. Assistance was also received from Dr. Don Ermak (SLAB model), Mr. Arnold Marsden (HEGADAS model), and Mr. Bruce Kunkel (AFTOX model) who reviewed those portions related to their respective models. Ms. Brenda Cannady typed the document.

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1.0 Introduction

The "Guideline on Air Quality Models (Revised)" (EPA, 1986) describes screening and refined air quality modeling techniques that focus on the six criteria pollutants (particulate matter, sulfur dioxide, nitrogen dioxide, carbon monoxide, ozone, and lead). Screening techniques are relatively simple and provide conservative estimates of the source impact. The purpose of such screening techniques is to eliminate the need for further, more detailed modeling when it is not necessary. Refined models provide more detailed treatment of physical and chemical atmospheric processes and require more detailed and precise input data. As a result, they provide a more refined and, at least theoretically, a more accurate estimate of source impact and the effectiveness of emission control strategies. Many of the models in the guideline have also been used in simulating air toxics releases. However, there is an increasing need to provide models that specifically address the impact of toxic air pollutants. Such models deal with both heavier than air (dense) and neutrally buoyant (non dense) releases.

To meet this need, EPA first published "A Workbook of Screening Techniques for Assessing Impacts of Toxic Air Pollutants" (EPA, 1988). The workbook provides a logical approach to the selection and use of appropriate screening techniques for estimating emission rates and ambient concentrations resulting from eighteen different types of air toxics release scenarios. EPA then developed the TSCREEN personal computer system (EPA, 1990a) that utilizes concepts found in expert systems to implement the scenarios described in the workbook. EPA also co-sponsored the development of the DEGADIS refined dense gas model (EPA, 1989a) and conducted a statistical model evaluation study of seven dense gas models using three experimental programs (EPA, 1990b). Several other documents have been published to show the user how to apply air toxics models. Among these are Hanna and Drivas, 1987; CCPS, 1988; and Britter and McQuaid, 1988. These documents provide an introductory understanding of the complex issues associated with air toxics modeling, especially those issues related to denser than air releases.

With the expanding interest in and use of air toxics models, there is also a need for general guidance on the use of refined models in order to foster consistency in their use. Refined air toxics dispersion models are used for a variety of purposes. One such application is the assessment of the hazard extent of a past or current event (i.e., a response analysis). For such an application, the maximum concentration at a given distance, e.g. a fenceline, is needed and this document shows the thought process the user should employ to estimate the input parameters based on actual conditions of the release. Another application of these models is for planning purposes. In these applications, the model user typically desires conservative estimates of the impact from a potential release under any condition. Sensitivity tests (Hanna et. al., 1990; Guinnup and Nguyen, 1991) have shown that predictions from some models may vary by an order of magnitude or more due to changing the input for the following meteorological parameters: wind speed, atmospheric stability class and surface roughness. The guidance provided here shows how to estimate values for these variables so that, when input into the refined models, there is an increased likelihood for obtaining the maximum concentration at a given distance.

Chapter 2 describes general guidance considerations needed to apply the atmospheric dispersion models described in this report. Chapter 3 applies the general guidance to several dense gas models that are in the public domain. These include the models DEGADIS, HEGADAS, and SLAB; other dense gas models will be added as they become available. Since each model may require unique and specific inputs, guidance for developing these unique model inputs is provided under the sub-heading of each model. Finally, for each model, two examples using the general guidance are provided. The examples include a definition of the release scenario, a step-by-step explanation of how the model was applied, and an interpretation of the model results. The two examples can not cover all of the release types that can be considered by these models. Chapter 4 applies the general guidance considerations to refined, neutrally buoyant (non-dense) air toxics dispersion models that are also in the public domain. Many of the EPA regulatory models that are described in the modeling guideline (EPA, 1986) fit this category. Since there is a lot of experience in the use of these models, they are not discussed here. Models developed specifically for air toxics releases and that contain features unique to such sources are the subject of this chapter. Presently, this includes the AFTOX model; other models in this category will be added as they become available. The organization of this Chapter is similar to Chapter 3.

Appendix A contains a summary outline for each dense gas model referenced in this guidance document and Appendix B provides a similar summary for the models used for neutrally buoyant releases into the atmosphere. The format for these model summaries is the same as that used in the modeling guideline (EPA, 1986). Appendices C and D contain a computer listing for the two example applications for each model. Appendix E contains guidance on calculating the temperature of released material.

Finally, this document is not intended to be a replacement for any model user's guide but should serve as a general supplement that provides additional information on the considerations needed to execute and interpret the various models discussed. As knowledge and experience in the use of refined air toxics models increase, updates to this document will be necessary. The unique approach used here makes this document a good supplement to many existing documents on air toxics modeling applications.

2.0 Model Input Considerations

This chapter describes the meteorological and source input parameters required for using air toxics dispersion models and provides general guidance on how to specify these parameters. In general, these input parameters should be based on site-specific data. Based on current experience, certain input parameters play a more important role in determining model concentrations. However, additional sensitivity analyses are useful in identifying the most important parameter for a specific model and scenario. The user should carefully examine each release scenario and use the appropriate model input parameter from those listed below. There is no universal approach for all cases.

2.1 Release Type

Air toxics models use differing methodologies to account for various release types, thus the user must know the release type before specifying the input parameters discussed here. Air toxics contaminants can be stored as a gas or as a liquid, under various amounts of pressure and temperature. When released to the atmosphere, a substance stored as a gas under pressure at ambient temperature will exit as a gas. When a substance stored as a liquid under pressure at ambient temperature, with a boiling point below ambient temperature, is released into the atmosphere, there is a high probability of aerosol formation (an aerosol includes both liquid and gas phases). When a substance stored as a liquid under pressure at ambient temperature, but with a boiling point above ambient temperature is released, the release will most likely form a liquid pool. This liquid pool will subsequently volatilize into the atmosphere (evaporate) at a rate proportional to its vapor pressure. Low volatility liquids (low vapor pressure) evaporate more slowly and tend to form larger pools than high volatility liquids. The contaminants can be stored as a pure substance (e.g., ammonia) or a mixture (e.g., liquefied natural gas). Materials stored at temperatures other than ambient may require more complex thermodynamic analyses to determine the exact release phase and such calculations are not addressed in this document. Other complex situations such as those involving materials which react with the atmosphere are also not addressed.

2.2 Continuous or Instantaneous Release Categories

For modeling air toxics, there are two release categories: continuous (steady-state) or instantaneous (transient). In steady state releases, source characteristics do not vary with time (i.e., emission rate is constant), and the release duration is long compared to advection (travel) time. A release is considered transient if the source characteristics do not vary with time but the duration of the release from the source is limited. A transient simulation of a release is required under any of the following conditions: a) an instantaneous release; b) some characteristics (including release rate or diameter) vary with time; or c) source duration is short compared with the contaminant advection time to a given location or the averaging time for predicted concentrations.

The user can determine if the advection time is long compared with the release duration by using the following empirical procedure:

1) Make a steady-state simulation of the release and determine the maximum distance to the lowest concentration of interest, X_L.

2) Estimate the advection (travel) time to that distance as:

$$t_{trav} \simeq 2 \ (X_L/u)$$

where: u = the ambient windspeed (typically at 10m).

3) If t_{trav} is smaller than the source release duration, then a steady-state simulation is probably sufficient. Otherwise, the release may be instantaneous.

While the examples discussed in this document are limited to continuous releases, many of the guidance considerations also apply for transient releases.

2.3 Molecular Weight

For a single component gaseous contaminant (e.g. NH_3 gas), molecular weight can be obtained from typical chemistry or chemical engineering handbooks (e.g., Perry and Green, 1984). For a multi-component mixture, an average molecular weight can be calculated as follows:

If volume (or mole) fractions are known:

$$M_s = \sum_{i=1}^{n} y_i \, M_i$$

where: Ms = mean molecular weight of material released (g/g-mole);

y_i = the volume (or mole) fraction of component; and

M_i = molecular weight of each component (g/g-mole).

If mass fractions are known:

$$M_s = \left(\sum_{i=1}^{n} \ (m_i/M_i) \right)^{-1}$$

where: m_i = mass fraction of each component.

For aerosols made up of a single component, the molecular weight can also be obtained from textbooks or handbooks as discussed above for pure gases. For aerosol mixtures, an average molecular weight can be calculated using the equations above with either mole or mass fractions, but not volume fraction.

2.4 Heat Capacity

If the temperature of the released toxic cloud is significantly different from ambient, heat transfer effects may be important, and the heat capacity of the released material will be needed to calculate cloud density as it disperses. Heat capacity values can be obtained from typical handbooks (e.g., Perry and Green, 1984). If the toxic contaminant is a mixture, the average heat capacity of the mixture can be approximated by:

$$\overline{C}_{p_m} = \sum_{i=1}^{n} y_i \, \overline{C}_{p_i}$$

where: Cp_m = molar heat capacity of the mixture (J/kg-mole K);

y_i = mole fraction of component i in the mixture; and

Cp_i = molar heat capacity of component i of the mixture (J/kg-mole K).

Alternatively, the heat capacity (on a mass basis) can be calculated as:

$$C_{p_m} = \sum_{i=1}^{n} m_i \, C_{p_i}$$

where: $\tilde{C}p_m$ = heat capacity per unit mass (J/kg K);

m_i = mass fraction of component i in the mixture; and

$\tilde{C}p_i$ = mass heat capacity of component i in the mixture (J/kg K).

The molar heat capacity is directly related to the mass heat capacity by the expression:

$$\overline{C}_{p_m} = C_{p_m}/M_s$$

where: M_s = molecular weight of the mixture (kg/kg-mole).

If a gaseous contaminant is released so that the temperature of the gas is the same as ambient temperature, then the heat capacity is not important in the dispersion calculation. If required, the heat capacity for the gas can be obtained from typical handbooks or the model user's guide. If the released material is an aerosol, calculation of heat transfer effects during the cloud dilution is complex and is not generally included in a dispersion model. In such a case, the user may need to externally calculate the relationship between air/contaminant mixture density and contaminant concentration. (For example, the DEGADIS model may be used to simulate an aerosol release by providing externally-calculated cloud densities as inputs.)

Some models require specification of a heat capacity through a parameterized function. In these cases, the user will need to input the appropriate values of the parameters. Such parameters are typically provided in the model user's guide.

2.5 Release Temperature

This parameter is the temperature of a released pollutant as soon as it gets into the atmosphere, after any necessary depressurization. Some dispersion models include a source model which attempts to calculate this parameter; in such cases, the models may require the material storage temperature rather than the release temperature. If the release temperature is different from ambient air temperature, heat transfer into or out of the cloud may be important. When heat transfer is important, a thermal energy balance is needed which can account for: (a) energy addition to the plume due to ambient air entrainment; (b) heat transfer at the plume boundaries; (c) latent heat exchange due to condensation of the moisture content of entrained humid air and any subsequent reevaporation as the saturation conditions change with downwind distance. For aerosol releases, energy balance considerations are also needed to account for the latent heat effects due to evaporation of the liquid contaminant phase. The treatment of these issues varies from one model to another.

For release of a gas, stored at low to moderate pressure (i.e., less than about 5 atm), the exit temperature may be assumed equal to storage temperature; when stored at high pressure (i.e., above about 5 atm), the gas exit temperature may be calculated by taking into account the adiabatic expansion of the gas after it exits from the relief valve. This temperature would generally be lower than the storage temperature. The temperature of the depressurized release can be calculated assuming isenthalpic behavior (neglecting kinetic energy effects) or assuming isentropic behavior (including kinetic energy effects). The isenthalpic assumption is generally more conservative and is therefore preferred. Appendix E contains examples of this approach for making temperature calculations.

For releases which form aerosol clouds, the release temperature can be assumed equal to the boiling point temperature. For releases which form liquid pools (see Section 2.1), estimating the release temperature is complex and depends, for example, on the rate of heat exchange of the spilled liquid with the surface. An evaporation (or source) model is required to make this estimate. For example, some models assume the pool temperature is equal to the ambient temperature and calculate the evaporation rate at that temperature.

2.6 Density

Initial cloud density is an important determinant of cloud extent. The denser the cloud is initially, the more it will tend to spread laterally (and even potentially upwind) due to gravitational "slumping" or spreading forces. In addition, the changes in cloud density downwind are dependent on the rate of heat transfer into the cloud. For example, one effect of heat transfer into a cold cloud is to reduce the negative buoyancy (i.e., decrease density) and, thus, to reduce the horizontal dimensions that result from gravitational spreading. The effect of heat transfer into an aerosol cloud is to vaporize the aerosol droplets, thereby, reducing the total cloud density. However, such vaporization will also tend to reduce the cloud temperature below its boiling point and thus increase the total cloud density. Prediction of aerosol cloud densities may further be complicated by chemical reaction in the liquid phase (as in polymerization of hydrogen fluoride) or interaction with ambient humidity (as in pressurized ammonia and hydrogen fluoride releases). The treatment of aerosol cloud density in dense gas models is model specific as is the degree of available simplification of the cloud density/ concentration relation. Most models, however, do require specification of the initial cloud density (prior to any dilution in the atmosphere).

For a gaseous release, initial density can be estimated by specifying the release temperature and molecular weight and using the ideal gas law.

For an aerosol release, initial cloud density may only be calculated if the relative amounts of liquid and vapor in the release are known. This can be approximated for single-component release via a flash calculation. For a simple case, consider the release of a single component pressurized (saturated) liquid stored at ambient temperature, which is above its normal boiling point. The relative amounts of liquid and vapor formed upon release can be estimated by performing an adiabatic flash calculation with the following equation (see Section 4.13 of the workbook (EPA, 1988)):

$$F = C_{p_L} \frac{(T_{st} - T_b)}{L}$$

where: F = mass fraction of liquid flashed to vapor;

Cp_L = specific heat of liquid at constant pressure at T_b (cal/(g K));

T_{st} = storage or line temperature of liquid (K);

T_b = boiling temperature at ambient pressure (K); and

L = latent heat of vaporization at T_b (cal/g).

If all the unflashed liquid is entrained in the gas jet as an aerosol, the initial density of the release mixture prior to any air entrainment can then be estimated:

$$\rho_{rel} = [(F/\rho_v) + (1-F)/\rho_L]^{-1}$$

where: ρ_{rel} = density of the undiluted aerosol mixture (g/cm^3);

ρ_v = pure vapor density at T_b (g/cm^3); and

ρ_L = pure liquid density at T_b (g/cm^3).

Since the release is a single component, the mixture density is also equal to the contaminant concentrations for the undiluted aerosol. If $F \geq 1$, the release is not expected to form an aerosol, and may be conservatively assumed to form a pure gas release at its normal boiling point temperature.

For multi-component releases, the calculation is complex and iterative and the user is referred to King (1988), pp. 68-90.

The density of a substance which forms a liquid pool (see Section 2.1) can be obtained from typical handbooks, if needed by the model.

2.7 Release Diameter (Release Area)

For stack releases, this parameter should be determined from direct measurement from inside the stack top. For some applications, a gas may be slowly released from a rupture or a hole. In those cases, the inside diameter of the rupture point or hole may be used. However, when the source is a pressurized jet, the release diameter (D_r), required by a dispersion model is typically the diameter of the released jet after it has depressurized to atmospheric pressure. Assuming that the jet velocity remains constant within the depressurization region, the release diameter can be estimated from:

$$D_r = (\rho_{st}/\rho_{rel})^{1/2} D_s$$

If the stored and released materials are both gases, this reduces to:

$$D_r = [(P_{st}/P_{amb})\ (T_{rel}/T_{st})]^{1/2} D_s$$

where: ρ_{st} = density of stored material at D_s (g/m^3); ρ_{rel} = density of the released material upon depressurization to ambient air (g/m^3); D_s = hole diameter (at the source) (m); P_{st} = storage pressure (atm); P_{amb} = ambient pressure (atm); and T_{st} = source storage temperature (K). The release temperature (after expansion), T_{rel} (K), can be estimated assuming that it expands adiabatically (see Appendix E).

If the released material forms an aerosol, calculation of the release diameter will depend on appropriately accounting for the flashed fraction to estimate the release density at atmospheric pressure (refer to Section 2.6 for how to calculate (ρ_{rel})).

For liquid spills, a pool diameter is needed. Screening estimates for determining pool diameter are given in the workbook (EPA, 1988).

2.8 Release Buoyancy

It is necessary to determine whether the released material is heavier than air (dense) or neutrally buoyant for a specific release scenario before an appropriate dispersion model can be selected. This determination is done step-wise and begins with an estimate of the molecular weight of the released material. Once the molecular weight has been determined, the density of the released material as described in Section 2.6 can be compared to the density of air to initially determine negative (dense gas) or neutral buoyancy. For ideal gases, the following relationship can be used:

If:

$$\frac{T_s}{M_s} \geq \frac{T_a}{28.9}$$

where: Ta = ambient temperature (K); and

Ts = temperature of the material released at ambient pressure[1]

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[1]Note that a liquid whose boiling point is below ambient temperature, stored at ambient temperature under pressure may boil when released to ambient pressure. Then the temperature of the released material at ambient pressure may be assumed to be the normal boiling point.

(K); then, atmospheric dispersion is not affected by negative buoyancy effects and dense gas models are not required.

If the initial release buoyancy determinations show that dispersion is affected by negative buoyancy (i.e., dense gas effects are important and a dense gas model is necessary), then the next step is to determine the release Richardson number (Ri). Ri represents a ratio of the potential energy characteristic of the release to a measure of the ambient turbulent kinetic energy.

The approach recommended for determining Ri is that described in the workbook (EPA, 1988). Pages 5-2 through 5-5 of the workbook provide a procedure for making the calculations for simple cases. For more complex situations, e.g., elevated jet releases, the TSCREEN model (EPA, 1990) may be used to make these calculations. In either case, if Ri for a particular wind speed/stability class combination is greater than 30, then dense gas effects should be considered.[2] Models described in Chapter 3 are appropriate for determining downwind concentrations from dense gas releases. If R_i is less than or equal to 30, the release is considered buoyant. Although some of the models in Chapter 3 are able to address buoyant releases, it is suggested that the user selects one of the models in Chapter 4, or one of the EPA regulatory models because they are easier to use than the dense gas models.

2.9 Emission Rate

When assessing the emission rate for a specific release scenario, several time scales may be encountered and this "time-history" of the emission rate

[2]A large Ri indicates the dominance of buoyancy forces over shear forces. A cut-off value of 30 is consistent with the RVD screening model (EPA, 1989b), which is imbedded in TSCREEN.

can have a significant influence on the final modeled concentration estimates. For a pressurized release, three time scales could be encountered; the initial high volume emission rate followed by a near steady state rate and finally a drop to zero as the leak stops. Evaporation from spilled releases may exhibit other patterns. Therefore, to estimate emission rates, methods based on direct measurements are preferred. In general, emission rate (expressed as mass per unit time) equals emission density (mass/volume) times total volumetric flow rate (volume/time). If direct measurements are not available, emission rate can be estimated from the release mode and duration. For selected release scenarios, methods for obtaining emission estimates are shown in the workbook (EPA, 1988).

2.10 Release Height

This parameter should be determined from direct measurement from the ground level at the base of the stack or the release point up to stack top. Some models adjust the wind speed (from the measurement height) to the release height. For a non stack-type release, the release height represents the vertical distance from the ground level to the center of the initial release.

2.11 Wind Speed and Direction

Wind speed is used to determine (1) plume rise, (2) plume dilution, and (3) mass transfer in evaporation models. In very light winds, dense gases tend to form "pancake-shaped" clouds near the source and the dense cloud may not be very deep until further downwind. As wind speed begins to increase, the "maximum concentration" area moves further downwind and the cloud is elongated and maximum hazard extent generally increases. At higher wind speeds, the rate of air mixing is increased (more energy is added to the mixture) and the hazard extent decreases. For releases from liquid pool spills, high wind speeds increase the rate of evaporation and thus increase the plume source strength. However, high wind speeds also result in more dilution due to increased entrainment of outside air and are more favorable for atmospheric dispersion.

Concentration estimates predicted by air toxic models decrease as the wind speed increases (Hanna et. al., 1990). However, most dense gas models are less sensitive to this increase in wind speed at close-in distances, where gravity effects are dominant. Further downwind, the behavior of dense gas models and non dense gas models is more similar. In a comparison of the three dense gas models SLAB, DEGADIS and HEGADAS, the three models exhibit different sensitivity in modeled concentrations due to changes in wind speed. The SLAB model is most sensitive while DEGADIS and HEGADAS show about the same degree of sensitivity to changes in wind speed (Guinnup and Nguyen, 1991). In addition, all models indicate that an increase in wind speed causes a dramatic reduction in the lateral dimension of the concentration isopleth with a less dramatic reduction in downwind extent for a ground level dense gas release.

If the user wishes to assess the hazard of a past event, wind speed should be obtained from on-site measurements usually made at the standard 10m level height. The wind speed at release height is frequently adjusted internally by the model using a power law equation. Guidance for on-site meteorological data collection is available in the document "On-site Meteorological Program Guidance for Regulatory Modeling Applications" (EPA, 1987). On-site meteorological data are normally averaged over a 1-hour interval. As described in Section 2.16, for transient releases the user should carefully select the appropriate meteorological data interval (i.e., the subset of time that the plume remains in the area of concern).

The wind direction is used to approximate the direction of transport of the plume. The variability of the direction of transport over a period of time is a major factor in estimating ground-level concentrations averaged over that time period. For response analyses, wind direction should be estimated from on-site or nearby measurements. For planning analyses, wind direction should be chosen to maximize potential off-site impacts.

2.12 Stability Class

Stability conditions are typically assessed by means of the Pasquill-Gifford (PG) stability categories where Category A represents extremely unstable conditions and Category F represents moderately stable conditions. The modeling guideline (EPA, 1986) recommends several methods for determining the PG stability category.[3]

For a given wind speed, stable atmospheric conditions provide smaller levels of atmospheric turbulence than unstable conditions. The influence of atmospheric stability on the dispersion of a dense gas (as a result of altered levels of ambient turbulence) may be similar to that for neutrally buoyant releases, but may also be much less. For elevated releases, stable atmospheric conditions tend to increase the downwind distance to a given concentration (and unstable conditions tend to reduce it). For dense gas models, the maximum ground level concentration at a given distance usually occurs under stable conditions. As in the case of wind speed, various models

[3] These methods may change and the user should refer to the latest revisions to the guideline.

exhibit different sensitivity levels in concentration prediction due to changes in stability class (Hanna et al., 1990, Guinnup and Nguyen, 1991).

For planning analyses, where there is a need for obtaining conservative estimates from these models, it is necessary to make a number of refined model simulations using various stability and wind speed combinations. For the dense gas models included in this report, making a large number of simulations and interpreting their results is a daunting task. Therefore, the following approach is suggested. For vertically directed jet releases, the user should first apply the RVD screening model imbedded in TSCREEN (EPA, 1990). The model has a built-in range of wind speeds with associated stability categories. The user then selects the wind speed and stability assosciated with the maximum concentration at the fenceline distance. This wind speed and stability combination is then input to the refined dense gas model. For liquid pool spills, a wind speed of 2 m/s and F stability class can be used.

The above procedure has shortcomings. For example, the wind speed and stability combinations in the screening model may not be the same combination that would yield the maximum concentration in the refined model due to differences in model "physics" and other assumptions. Also, the wind speed and stability combination may strongly depend on whether the release can be simulated as a steady state or as a transient release. For spills, low wind speeds are not favorable for evaporation. Nevertheless, simulating the release with wind speed and stability class described above provides the user with an initial assessment of the problem before applying the more complex refined model.

2.13 Surface Roughness Length

In principle, the surface roughness length is a measure of the roughness of a surface over which a fluid is flowing and for a homogeneous surface, its value may be approximately estimated as 1/30th of the average height of the surface irregularity. When the landscape contains any obstructions (i.e, nonhomogeneous), an effective roughness length must be determined. The effective length is best determined using the relationship described in the meteorological data guidance document (EPA, 1987). Typical values of surface roughness are shown in Table 2-1. Some models use surface roughness to internally compute the Monin-Obukhov length.

The overall effects of increasing surface roughness will be to retard the horizontal, buoyancy-induced spreading of the plume or cloud and to enhance the mixing between plume and environment as a result of the ambient and plume turbulence (Britter and McQuaid, 1988). As in the case of wind speed and stability class, various models exhibit different sensitivity levels in predicted concentrations due to changes in surface roughness (Hanna et al., 1990; Guinnup and Nguyen, 1991). Because releases of a dense gas may occur in industrial settings where the presence of a wide variety of structure heights and shapes is common, some users have input large surface roughness values into a model to account for the presence of such obstacles. However, these large surface roughness values can significantly decrease modeled concentrations. For low or ground-level releases, increasing the surface roughness value by a factor of 10 may result in concentration reductions by about a factor of 2 (Petersen, 1989). The use of "enhanced" roughness values for simulating an industrial setting has yet to be thoroughly tested and justified. For planning analyses where there is a need for obtaining conservative estimates from these models, the use of a surface roughness value characteristic of the smallest roughness element in the vicinity of the release (typically around 0.01 m) will result in the prediction of a higher concentration by the model.

2.14 Ambient Temperature, Relative Humidity, and Pressure

To assess the consequences of a past event, input parameters should be used which are representative of the conditions at the time of the release. An appropriate input value for each of these parameters should be obtained from on-site measurements at the time of release. Guidance on methods for collecting these data are presented in the meteorological data guidance document (EPA, 1987). If on-site data are not available for these parameters, observations from nearby National Weather Service (NWS) stations may be used instead.

Experience to date indicates little, if any, sensitivity in predicted model concentrations due to changes in these three parameters. For planning analyses, the input of a value typical of the climatological average is usually adequate.

2.15 Ground Surface Temperature

An appropriate input value for ground surface temperature should be that from routine on-site measurements. If such data are not available, ground surface temperature may be approximated to be equal to ambient temperature measured at the standard height, for most applications. Experience to date indicates little, if any, sensitivity in predicted model concentrations due to changes in this parameter.

2.16 Averaging Time Considerations

Toxic chemical releases are often of short duration and the concentrations of interest are short term averages. Typical concerns from a toxic release are the maximum short term concentration and the maximum dosage. Many toxics models are designed to provide concentration predictions for unit averaging times ranging from 1 second to 1 hour. By contrast, regulatory models for most criteria pollutants have a basic averaging time of one hour for concentration estimates.

Refined dense gas models can typically provide concentration estimates for user specified averaging times of 1 hour or less. Due to entrainment with ambient air, a dense gas release typically does not remain significantly dense for travel times longer than 1 hour. The length of the averaging time is usually selected in order to evaluate the exposure to airborne chemicals. Meteorological input, however, is often based on an hourly average. To determine the appropriate averaging time the user should examine the persistence of meteorological conditions and the concentration levels of concern keeping health or other reference levels in mind.

Defining an appropriate averaging time for dense gas modeling application is complicated. Large averaging times allow for more plume meander and therefore lower average concentrations. Thus, a 5-minute ensemble average concentration is generally less than a 1 minute ensemble average since more meander can generally occur in 5 minutes than in 1 minute. Thus, some researchers use much shorter averaging times (i.e., 5-10 seconds), than the release duration, especially when comparing model predictions with field measurements when these field measurements are made with shorter averaging times. However, meteorological inputs (i.e. stability classification) used in conjunction with these models are based on a longer duration, usually 60 minutes.

The time scales relevant to determining the averaging time to be used in the models can be designated as:

t_{haz} = averaging time associated with the hazard being assessed;

t_{rel} = duration of the contaminant release; and

t_{trav} = travel time, discussed earlier (Section 2.3).

If t_a is the averaging time which represents the effect of plume meander, then the largest recommended t_a is the minimum of t_{haz} and t_{rel} (for steady-state or transient releases); smaller values of t_a can be chosen to compare with field observations. If $t_{a,t}$ is the averaging time which accounts for transient effects (not pertinent for steady-state releases) $t_{a,t}$ is recommended to be t_{haz}.

Table 2-1

REPRESENTATIVE VALUES OF SURFACE ROUGHNESS FOR A UNIFORM DISTRIBUTION OF SELECTED TYPES OF GROUND COVER (PIELKE (1984))

	Surface Roughness (m)
Ice	0.00001
Snow	0.00005 to 0.0001
Sand	0.0003
Soils	0.001 to 0.01
Short grass	0.003 to 0.01
Long grass	0.04 to 0.10
Agricultural crops	0.04 to 0.20

3.0 Application to Dense Gas Models

This chapter narrows the focus of the general guidance considerations developed in Chapter 2 and deals with input requirements for each specific dense gas model. At the present time, three models are discussed: DEGADIS, HEGADAS and SLAB. Table 3-1 shows the types of releases considered by these dense gas models. Significant model attributes should be carefully taken into consideration when selecting a model for a given application. For each model, the discussion begins with those specific input parameters that can not be readily obtained from reviewing the model user's guide. For each model, two example applications are provided to show the user how every model input parameter was derived. The present examples do not cover all of the release types that can be considered by these models.

3.1 DEGADIS Model

The DEnse GAs DISpersion (DEGADIS) Model (Version 2.1) (EPA, 1989b) is designed to model the dispersion of dense gas (or aerosol) clouds released from a circular source cloud at ground level with no initial momentum (pooled surface) as well as the dispersion of vertical jets. The DEGADIS model summary description is included in Appendix A.1. There are terms used in DEGADIS (i.e., isothermal and nonisothermal) that need distinction.

a. Isothermal and Nonisothermal Simulation

An "isothermal" simulation means that DEGADIS does not use an energy balance to relate contaminant concentration to mixture density; for an "isothermal" simulation, the user must supply this relationship in the form of ordered triples (of contaminant mole fraction, contaminant concentration, and mixture density). "Isothermal" simulations are useful for both aerosol releases and releases where the initial contaminant temperature is the same as the ambient temperature.

A "nonisothermal" simulation means that DEGADIS uses an energy balance to determine the cloud temperature (and thereby its density) as air is mixed with the cloud. The energy balance allows for ground-to-cloud heat transfer and accounts for thermal effects associated with the condensation of ambient humidity, but the energy balance does not account for thermal effects associated with contaminant phase changes (as in aerosol releases). The energy balance assumes the contaminant is an ideal gas. "Nonisothermal" simulations are useful when the released contaminant can be represented as an ideal gas and the initial contaminant temperature is significantly different from ambient temperature.

b. Density Considerations

If the release being modeled is an aerosol, the DEGADIS model requires data relating the cloud density to its contaminant concentration level. In order to calculate the density of a cloud for any given dilution with air, the user must know:

1. the heat capacities of the liquid and vapor phases;
2. the heat capacity of the ambient air and its contained moisture; and
3. the latent heat of vaporization of the released contaminant and water.

This information is then used (in adiabatic mixing calculations, i.e., no heat transfer) to determine the liquid and vapor contents of the released cloud/ambient air (aerosol) mixture.

As one varies the input amounts of air and released aerosol from pure (100 percent) air to pure (100 percent) aerosol, the density of the resultant mixture will change. [So will temperature T, liquid content (l), vapor content (v), and concentration (c)]. The adiabatic mixing calculations result in values for contaminant mole fraction, contaminant concentration (kg of contaminant per m^3 of contaminant/air mixture) and mixture density (kg of contaminant/air mixture per m^3 of contaminant/air mixture) which are then input to the DEGADIS model. Typically, this calculation is made 10 to 20 times using a combination of pure air and aerosol mixtures to adequately describe the complete density profile. The actual number in this combination series is then input to the model as a variable "NDEN" and the mole fraction/contaminant concentration/mixture density data are input on subsequent input records (see Section A of the user's guide).

Since calculating 10 to 20 combination data points can be tedious, one alternative, which generally provides results within acceptable error limits, is to provide the model with only the initial and final mole fraction/concentration/density data points; namely, those for the pure ambient air and pure aerosol as initially released. The model will linearly interpolate between these two end points. For the first end point, pure ambient air, the density entry value can be obtained from a psychometric chart (e.g., see Felder and Rousseau, 1986). The first end point value can also be obtained while running the DEGINP or JETINT modules of the DEGADIS model. Values for the second entry, pure aerosol, may be estimated if the relative amounts of liquid and vapor in the release are known, as described in Section 2.5.

c. Heat Capacity Considerations

In DEGADIS, constants for determination of cloud heat capacity are only needed if a "nonisothermal" simulation is being made, (i.e., contaminant release temperature differs significantly from that of ambient air and an energy balance is used to estimate the cloud temperature). The contaminant heat capacity is determined by Equation A.1 of the user's guide (EPA, 1989b). A constant heat capacity can be specified by setting the power (p1) to 0 and the constant equal to the desired heat capacity (J/kg K).

The temperature difference between the release temperature and the ambient temperature can be considered important if ambient humidity can be condensed (which is possible if the release temperature is below the ambient dew point). If the difference between the release temperature and the ambient temperature is not great, the variable "NDEN" may be set equal to -1; a pseudo "isothermal" simulation is made. The model calculates pure air and pure contaminant densities based on input conditions and then linearly interpolates between these end points. The model still requires inputs for variable "CPP" and CPK" but dummy values for these variables may be entered since the model will not use these variables when NDEN = -1.

d. Example Applications:

DEGADIS Model Example 1: Continuous Chlorine Leak

In this hypothetical example, the DEGADIS model is used for planning purposes to simulate the release of chlorine gas from a pressurized tank through a 2.8 cm diameter hole. Chlorine is being stored as a gas in a large tank at ambient temperature under 6 atmospheres of pressure[4]. The hole is

[4]In this example, since chlorine is released as a gas and remains as a gas after depressurization, there is no need to consider any aerosol effects.

located 5m above ground and the release is directed upward. Terrain in the vicinity of the tank is flat and covered with grass. Chlorine forms a greenish-yellow gas with a characteristic, irritating odor. The NIOSH 15-minute exposure limit is 0.5 ppm. Maximum off-site concentrations from this release are desired. Additional parameters are given as: molecular weight = 70.9 g/g-mole; ambient temperature = 298 K; heat capacity at constant pressure for chlorine gas = 500 J/kg K; ratio of specific heats = 1.35; and relative humidity = 50 percent.

Using the approach suggested in Chapter 2, the user begins by using the procedure shown in the workbook (EPA, 1988) and the TSCREEN model. This scenario is the same as Example 6.5 of the workbook. First, buoyancy and density are determined. The value for the Richardson number is well in excess of 30 indicating the need for a heavy gas model, and the RVD screening model imbedded in TSCREEN is used to select the wind speed and Pasquill stability category for input into a refined dense gas model. The screening model results are reviewed to determine the maximum concentration at the facility fenceline (100m). This concentration occurs within stability classes E and F at 2 m/s wind speeds. The F stability and 2 m/s wind speed parameters are selected as input into the DEGADIS refined dense gas model.

The DEGADIS input file for this example is shown in Appendix C.1. The description of the input elements below is done line-by-line from what is shown in the input and output files. The user can refer to pages A-6 thru A-8 of Appendix A of the DEGADIS model user's guide for additional definitions of terms.

1. **Line 1**

   UO = 2 m/s. UO is the ambient wind speed at reference height.

   ZO = 10 m. ZO is the reference height. This is the standard reference height for meteorological measurements.

2. **Line 2**

   ZR = 0.01 m. ZR is the surface roughness. This value is typical of terrain covered by grass. See Table 2.1.

3. **Line 3**

   INDVEL = 1. This indicates that the ambient velocity profile will be calculated using the Pasquill-Gifford stability category along with the surface roughness to estimate the Monin-Obukhov length RML. Using RML, the log velocity profile is then fixed.

   ISTAB = 6. This is the Pasquill-Gifford F stability category.

   RML = 0. RML is the Monin-Obukhov length. Since INDVEL = 1, the Monin-Obukhov length will be estimated by DEGADIS, and a dummy value of 0.0 is used.

4. **Line 4**

   TAMB = 298 K. TAMB is the ambient temperature.

   PAMB = 1 atm. PAMB is the ambient pressure. The exact magnitude for this parameter is not important for most releases.

   RELHUM = 50 percent. RELHUM is the relative humidity. Since the contaminant temperature is not below the ambient dew point temperature, this parameter will have little impact on the final result.

5. **Line 5**

   TSURF = 298 K. TSURF is the surface temperature. This value is usually set equal to the ambient temperature unless otherwise known.

6. **Line 6**

GASNAM = CL2. The three letter designation for the contaminant (Chlorine) is for documentation purposes only.

7. **Line 7**

GASMW = 70.9. GASMW is the contaminant molecular weight for chlorine.

8. **Line 8**

AVTIME = 900 sec. (15 min.). AVTIME is the averaging time. This averaging time is used to assess the concern for public health as discussed above. Here, we can compare the model predictions against the NIOSH Exposure Limit of 0.5 ppm for 15 minutes.

9. **Line 9**

TEMJET = 284.3 K. TEMJET is the temperature of the released contaminant immediately after it is released into the atmosphere. The cooling due to adiabatic expansion of the jet is calculated using the method in Appendix E.

10. **Line 10**

GASUL = 5×10^{-6} mole fraction. This is the higher of two concentration levels to be used for estimating contours. The upper concentration limit is arbitrarily selected to be a factor of 10 higher than the NIOSH 15-minute exposure limit of 0.5 ppm. This ppm value is converted to mole fraction by dividing by 10^6.

GASLL = 0.5×10^{-6} mole fraction. This is the lower of two concentration levels to be used for estimating contours. The lower concentration limit is selected as the NIOSH 15-minute exposure limit of 0.5 ppm converted to mole fraction by dividing by 10^6.

ZLL = 0 m. ZLL is the receptor elevation for contour predictions. A ground level concentration is desired.

11. **Line 11**

INDHT = 1. This is a switch to indicate if heat transfer is to be included in the model. Since the release temperature is different than the ambient temperature, heat transfer should be included and INDHT = 1. CPK (heat capacity constant) and CPP (heat capacity power) are variables used to calculate heat capacity according to the equation used in the model. To use a constant value of heat capacity for chlorine of 500 J/kg K, set CPK = 500 and CPP = 0.

12. **Line 12**

NDEN = 0. This variable is used to specify the contaminant density profile. For this release, the chlorine is a gas after depressurization. When NDEN is set to zero a "nonisothermal" situation (where the energy balance is used to determine cloud density) is made; also, the initial contaminant density is calculated using the ideal gas law.

13. **Line 13**

ERATE = 1.261 kg/sec. ERATE is the contaminant emission rate. See page 6-14 of the workbook for details on how this value can be calculated.

14. **Line 14**

ELEJET = 5 m. ELEJET is the initial jet elevation. In this case, the rupture hole is 5 m above ground.

DIAJET = .06701 m. Since the release is pressurized, the diameter of the release must be adjusted so the velocity will be calculated correctly by the model. In this case, both stored and released contaminants are gases, so:

$$D_r = \left[\left(\frac{P_{st}}{P_{amb}}\right)\left(\frac{T_{rel}}{T_{st}}\right)\right]^{1/2} D_s$$

$$\dot{D}_r = \left[\left(\frac{6}{1}\right)\left(\frac{284.3}{298}\right)\right]^{1/2} (0.028) = 0.06701m.$$

15. **Line 15**

TEND = 0. TEND is a switch indicating duration of the primary release. A value of zero indicates steady-state release. Several criteria are used here. A steady-state release is appropriate when storage capacity of the system is much larger than the release rate. In addition, the applicability of a steady-state simulation depends also on the advection or travel time to the lowest concentration of interest (t_{trav}) as discussed in Section 2.2. This step requires an examination of the output. The 0.5 ppm level is reached at 10.2 km from the source and 2 m/s is the ambient wind speed. Using the equation in Section 2.2, $t_{trav} = 2\ (X_L/u) = 2\ (10200/2) \approx 10{,}200$ sec. = 2.8 hrs. For this release rate, if the source duration is longer than 2.8 hours, then a steady-state simulation is justified.

16. **Line 16**

DISTMX = 100 m. DISTMX is the maximum distance between output points in the model. Note that this does not affect the concentration values predicted by the model; only the amount of output is affected.

Model Output

The DEGADIS model output file is shown in Appendix C.1. The output file first shows a summary of model inputs. Some of the parameters were calculated directly by the model. The model output then lists the centerline concentrations by downwind distance for the jet/plume phase of the release. For the jet/plume release, the maximum centerline ground level concentration is 7.49 x 10^{-4} mole fraction (749 ppm), at a distance of 220 m downwind of the release. The plume trajectory portion of the calculation ends at 261 m downwind. At this point the plume centerline is at ground level (zero). The maximum 5 ppm isopleth width in the jet/plume is 2 x 27.3 = 54.6 m at 261 m downwind.

When the plume centerline touches the ground, the DEGADIS model continues the calculations for the dispersion of a ground level plume. The output file again shows a summary of model inputs, together with additional ground-level "source" parameters calculated directly by the model. This is followed by a listing of the plume concentration as a function of downwind distance. In addition, cross wind distances to the specified concentration levels (.5 ppm and 5 ppm) are listed as a function of downwind distance in the last two columns. The higher specified concentration level 5 ppm (1.45 x 10^{-5} kg/m^3) is reached at a distance of 6170 m from the release point. The maximum 5 ppm isopleth width is 2 x 289 = 576 m at 2970 m downwind. Similarly, the lower specified concentration level 0.5 ppm is reached at a distance of 10,000 m downwind. The maximum 0.5 ppm isopleth width is 2 x 598 or 1200 m at the 10,200 m downwind distance.

DEGADIS Model Example 2: Ammonia Pipeline Rupture

The model is used here to assess the hazard extent of a past event which occurred at about 8:00 a.m. when a bulldozer struck and ruptured an 8-inch ammonia pipeline operating at approximately 700 psi. The rupture was estimated as 4 cm in diameter, and the release rate was estimated as 56 kg/s. The climatological data from the nearest National Weather Service station were examined and the following meteorological record reconstructed for this event: wind speed = 4.5 m/s (10 m), ambient temperature = 298 K, atmospheric stability class = D, relative humidity = 50 percent, and atmospheric pressure = 0.98 atmospheres. The dense aerosol plume reportedly etched a parabolic-shaped scar about 6 miles long and 1/2 mile wide on surrounding vegetation (mostly short grass). Ammonia is a colorless gas with a suffocating odor; it exists as a liquid under 700 psi pressure.

The input file is similar to Figure B.4 of the DEGADIS model user's guide. The input file used here is shown in Appendix C.1. The input parameters are described below. Also see page A-6 of Appendix A of the user's guide for additional term definitions.

The user should perform a flash calculation to estimate the percent of liquid flashed into vapor using the method given in the workbook ($F = Cp_L \times (Ts - Tb)/L$), or F = 4294 J/Kg k (298-39.72)K/1370840 J/kg) = 0.18).

1. **Line 1**

   UO = 4.5 m/s. UO is the ambient wind speed at reference height.

   ZO = 10 m. ZO is the reference height. This is the standard reference height for meteorological measurements.

2. **Line 2**

   ZR = .01 m. ZR is the surface roughness. This value is typical of terrain covered by short grass.

3. **Line 3**

   INDVEL = 1. This indicates that the ambient velocity profile will be calculated using the Pasquill-Gifford stability category along with the surface roughness to estimate the Monin-Obukhov length RML. Using RML, the log velocity profile is then fixed.

ISTAB = 4. Pasquill-Gifford stability D class.

RML = 0. RML is the Monin-Obukhov length. Since INDVEL = 1, the Monin-Obukhov length will be estimated by DEGADIS, and a dummy value of 0.0 is used.

4. **Line 4**

TAMB = 298 K. TAMB is the ambient temperature.

PAMB = .98 atm. PAMB is the ambient pressure.

RELHUM = 50 percent. RELHUM is the relative humidity.

5. **Line 5**

TSURF = 298 K. TSURF is the surface temperature. In absence of specific information, this value is usually set to the ambient temperature.

6. **Line 6**

GASNAM = NH3. A three-letter designation for the contaminant (ammonia) used for documentation purposes only.

7. **Line 7**

GASMW = 17. GASMW is the contaminant molecular weight for ammonia.

8. **Line 8**

AVTIME = 3600 sec. (1 hour). AVTIME is the averaging time. A 1-hr exposure concentration between 100 ppm and 1000 ppm is used to compare with vegetation damage.

9. **Line 9**

TEMJET = 239.7 K. TEMJET is the temperature of the released contaminant after depressurization. Since this release is an aerosol, assume that the post expansion temperature is equal to the normal boiling point. Note that this value is not used by the model if NDEN > 0, as described later.

10. **Line 10**

GASUL = 1000 x 10^{-6} mole fraction. This is the upper concentration level to be used for estimating contours. Since severe damage to vegetation was observed, a 1-hour exposure level of 1000 ppm is an estimate of the level that might indicate vegetation scarring. This value is chosen as the upper concentration limit. This ppm value is converted to mole fraction by dividing by 10^6.

GASLL = 100 x 10^{-6} mole fraction. This is the lower concentration level to be used for estimating contours. This ppm value is converted to mole fraction by dividing by 10^6.

ZLL = 0 m. ZLL is the receptor elevation.

11. **Line 11**

INDHT = 0. This is a switch to indicate if heat transfer between the atmosphere and a ground-level plume is to be included in the model. Since an aerosol is being simulated, heat transfer cannot be simulated with ground-to-cloud energy transfer because, at present, aerosol releases are simulated without using the thermal energy balance (an "isothermal" simulation).

CPK and CPP are variables used to calculate heat capacity according to the correlation in the model. Since heat transfer is not included, heat capacity information is not needed. However, since the model requires inputs in this space, dummy values of 0.0 and 0.0 are input.

12. **Line 12**

NDEN = 2. This variable is used to specify the contaminant density profile. At present, DEGADIS simulates an aerosol release with a user-specified concentration/density relationship (i.e., an "isothermal" simulation). Thus, NDEN > 0 switch is used to specify the concentration/density relationship which, in this case, is described by 2 ordered triplets. The first column is contaminant mole fraction, the second column is contaminant concentration, and the third column is the mixture density. The first triplet is for pure ambient air and the second is for pure released material. The first triplet is determined using the ideal gas law for ambient air:

$$\rho = (MW \cdot P_a)/(R \cdot T_a) = 28.9 \ x\ 101325/8314 \ x\ 298 = 1.154 \ kg/m^3$$

The second triplet is determined from an isenthalpic flash calculation for the released ammonia using the equation in Section 2.6.

$$\rho_{rel} = [(F/\rho_v) + (1-F)/\rho_L]^{-1}$$

ρ_{rel} = 1/[.18/.8658 + .82/682.8] = 4.782 kg/m^2

where ρ_V = [(17)(101325)]/[(8314)(239.7)] = .8658 kg/m^3, and

ρ_L for ammonia is 682.8 kg/m^3.

13. **Line 15**

ERATE = 56 kg/s. ERATE is the contaminant emission rate.

14. **Line 16**

ELEJET = 0m. ELEJET is the initial jet elevation. Note that the model will change ELEJET to 2 x ZR if the user sets ELEJET to 0.

DIAJET = .478 m. DIAJET is the initial jet diameter. Assuming the released material is entirely a liquid before depressurization, the method described in Section 2.7 is used to calculate D_r;

$$D_r = (\rho_{st}/\rho_{rel})^{1/2} D_s = (682.8/4.782)^{1/2} (.04) = 0.478m$$

where the liquid density of ammonia is 682.8, and density of ammonia upon depressurization air is 4.782. Area after expansion is 0.179 m^2.

15. **Line 17**

TEND = 0. TEND is a switch indicating duration of the primary release mode. A value of zero indicates a continuous release.

16. **Line 18**

DISTMX = 50m. DISTMAX is the maximum distance between output points in the model, arbitrarily chosen at 50 meters in this example. Note that small values of this parameter will increase the size and precision of the output, while large values will have the opposite effect.

Model Output

The DEGADIS model output file for this scenario is shown in Appendix C.1. First, the output shows a summary of model inputs with some additional parameters calculated directly by the model. The model output first lists the centerline concentrations by downwind distance for the jet/plume phase of the release; the maximum centerline ground level concentration is 2.21×10^{-2} mole fraction (22100 ppm) at a distance of 172 m downwind. The jet trajectory portion of the calculation ends at 217 m downwind. At this point, the plume centerline is at ground level. The maximum 1000 ppm isopleth width in the jet/plume trajectory portion of the model is 2 x 56.5 m = 113 m at 217 m downwind. The next portion of the output shows the plume centerline concentration beyond plume touchdown. The output file again shows a summary of model inputs and also lists additional parameters calculated directly by the model. The maximum extent of the 1000 ppm concentration level is about 2400 m downwind. The maximum 1000 ppm isopleth width is 2 x 262 = 524 m at 1320 m downwind. The maximum downwind extent of the 100 ppm concentration level is 7100 m downwind from the source. The maximum 100 ppm isopleth width is 2 x 606 = 1212 m at 3700 m downwind.

3.2 HEGADAS Model

The HEGADAS model (Witlox, 1988) simulates ground level, steady-state and transient releases of dense gases formed from liquid pool surfaces. The HEGADAS model summary description is shown in Appendix A.2. In applying the HEGADAS model, the user should follow the general modeling guidance criteria in Chapter 2. In running the HEGADAS model for the example applications, certain input parameters were found not to be adequately described in the model user's guide. Useful clarification for some of these input parameters is given below:

a. Water Vapor: Water vapor flux addressed in ISURF is the transfer of water vapor from a water surface to the cloud. For a release over land, this option is not needed, but the water vapor in the entrained air is still treated in the thermodynamic calculations. Therefore, the relative humidity will affect the calculation regardless of the value of ISURF.

b. Low Wind Speed: HEGADAS assumes that convection (flow of the gas with the ambient wind) is dominant over gravitational spreading. Very low wind speeds increase the likelihood that convection will not dominate. The lowest wind speed suggested for use with HEGADAS in the user's guide is 1.5 m/s.

c. Averaging Time: The dispersion parameters used are those for instantaneous concentrations. For a longer averaging time, the value given on page 21 of the user's guide along with a conversion formula should be used.

d. Example Applications

HEGADAS Model Example 1: Continuous Liquid Spill from a Pipe

For planning purposes, the HEGADAS model is used to simulate the release of unsymmetrical dimethylhydrazine liquid spilled from a leak in an unpressurized transfer pipe. Due to its low volatility, this substance forms a pool, and this pool is unconfined. This chemical was stored at ambient pressure and temperature, and the liquid did not form a jet upon release. The pool evaporation rate is assumed to reach a steady state after spreading such that the evaporation rate equals the pipe flow rate. Dimethylhydrazine is a fuming, colorless liquid carcinogen with a strong odor. An estimate of the 15-minute maximum off-site concentration is needed. The minimum distance between the center of the spill area and the plant fenceline is 100 m. Terrain in the vicinity is typically flat, covered by short grass. Note, this release is similar to Example 6.15 in the workbook (EPA, 1988). Other known variables are: contaminant molecular weight = 60.1 g/g-mole; liquid release rate = 78.6 g/s; spill pool area = 58.8 m^2; atmospheric temperature = 10°C, and relative humidity = 50 percent.

In HEGADAS, the spill pool area is required as input. According to the workbook, the spill pool area is the smaller of the confined release area or the area at which the evaporation rate equals the release rate. Since the release is unconfined, the spill pool area (58.8 m^2) is obtained from the evaporation rate formula given in the workbook. A square area is assumed.

The HEGADAS input file is shown in Appendix C.2. The input parameters are described line-by-line from what is shown in the input and output file. The user can refer to pages 11 and 14 thru 15 of the HEGADAS model user's guide for additional explanation of terms.

1. **Title HEGADAS-S Workbook Example 6.15**

   ICNT = Contours or content code = 0. This model control switch generates an output listing of the Richardson number, gas temperature, and gas volume concentration at each downwind distance.

ISURF = Surface transfer code = 3. This model control switch specifies that surface heat transfer is included by the model.

2. **Pool Data**

PLL = Source length = 7.67 m. This value is obtained from the workbook. Given a pool area of 58.8 m^2, and assuming a square area, pool length = pool width = 7.67 m.

PLHW = Source half width = 3.83 m. This value is ½ of 7.67 m.

3. **Ambient Conditions**

Zo = Reference height = 10 m. This is the standard height for meteorological measurements.

Uo = Wind velocity at height Zo = 1.5 m/s. Table 2-3 of the workbook suggests that for ground level releases maximum concentrations are predicted under very stable conditions and a low wind speed. A 1.5 m/s wind speed is the lower limit of applicability of this model.

AIRTEMP = Air temperature at ground level = 10°C.

RH = Relative humidity = 0.5. This value corresponds to 50% relative humidity.

TGROUND = Earth surface temperature = 10°C. This value was set equal to ambient temperature.

4. **DISPERSION**

ROUGH = Surface roughness parameter = 0.01 m. This value is typical of flat terrain covered by short grass. Since no other information is provided, a 0.01 m value provides a conservative estimate.

MONIN = Monin-Obukhov length = 10. This value is obtained from Figure 1, page 22 of the user's guide for F stability and surface roughness of 0.01m.

CROSSW = Cross-wind dispersion coefficients = 0.0705 (delta) and 0.902 (beta). The value of delta is derived from the conversion formula on page 21 of the user's guide for a 15-minute average. The value of beta is obtained from Table III-2 of the user's guide for F stability.

5. **CLOUD**

XSTEP = Output step length = 1.0. This model switch controls the downwind interval between rows of output data. The step length is a multiple of the source length (PLL). Thus, step length (1) times source length (7.67 m) = 7.67 m which is the reporting interval shown in output.

XMAX = Maximum calculated distance = 100. This is a number multiplied by the source length. Thus, 100 (7.67 m) = 767 m. This indicates the distance at which model execution and output are terminated.

CAMIN = Ground level centerline concentration at which calculation stops = 1×10^{-7} kg/m^3. This parameter is selected to be lower than the lower concentration limit (CL).

CU = Upper threshold concentration limit = 1.15×10^{-6} kg/m^3. This value is chosen as a factor of 10 higher than CL.

CL = Lower threshold concentration limit = 1.15×10^{-7} kg/m^3. The 15-minute STEL exposure limit for this chemical, 1.15×10^{-7}, is selected as the lower concentration limit for comparing concentrations.

6. **SOURCE**

FLUX = Gas emission flux = 1.34×10^{-3} kg/m^2/s. This value is obtained by dividing the given liquid release rate (.0786 kg/s) by the pool area (58.8 m^2). The pool area calculations are shown on Page 6-48 of the workbook.

TEMPGAS = Temperature of emitted gas = 10°C. Assume pool surface temperature is in equilibrium with ambient temperature.

CPGAS = Heat capacity of emitted gas = 150 J/mole/C. This value was obtained from a chemical engineering handbook. Note, the user's guide refers to this variable as specific heat of gas, which is also correct.

MWGAS = Molecular weight of emitted gas = 60.1 kg/k-mole. This value is obtained from a chemical engineering handbook.

WATGAS = Molar fraction picked up from water = 0. Since the spill occurs on land, no water transfer into the source cloud occurs.

Model Output

The HEGADAS model output file is shown in Appendix C.2. The output file first lists a summary of model inputs. Some of the parameters listed were calculated directly by the model. The output file lists the centerline concentration by distance from the source. The first two distances listed are within the source and are ignored. The ground level concentration on plume axis at 100 m from the center of the source is about 0.0018 kg/m^3. The last column provides the concentration in percent volume (mole percent) which at 100 m is 0.001248 volume percent. Multiply this value by 10^4 to obtain a plume concentration of 12.48 ppm. The columns marked YCU and YCL tabulate the crosswind distance to the point at which the concentration is reduced to the "upper concentration limit" of 1.15×10^{-6} kg/m^3 and "lower concentration limit" of 1.15×10^{-7} kg/m^3, respectively. At 100 m downwind, these distances are about 90 and 98 meters, respectively.

The model output is terminated at a distance of 763 m (or approximately 100 times PLL value of 7.67 m). The selected upper and lower concentration thresholds are reached beyond this distance. The user can re-run the model using a larger cut-off distance should there be a need to obtain the distances to these concentration levels.

HEGADAS Model Example 2: Continuous Liquid Spill from a Tank

In this example, the HEGADAS model is used to assess the hazard extent of a past event where chlorine liquid is spilled from a leak in a storage tank under 7 atmospheres of pressure. Upon release to the atmosphere, the spilled liquid formed a rapidly boiling pool confined to a diked area. A review of on-site meteorological records shows that the release occurred mid-day when the wind speed was 2 m/s; atmospheric stability condition was D; atmospheric temperature was 30°C; and relative humidity was 75 percent. The pool evaporation rate under these conditions was estimated as 3.0×10^{-2} $kg/m^2/s$. This chemical is a fuming, colorless liquid carcinogen with a strong odor. The minimum distance between the center of the spill area and the plant fenceline is 100 m. Other given variables are: contaminant molecular weight = 70.9 g/g-mole; boiling point temperature = -34°C; and spill pool area = 16 m^2.

The HEGADAS input file is shown in Appendix C.2. The input parameters are described below.

1. **Title HEGADAS-S Workbook Example 6.16**

   ICNT = Contours or content code = 0. This model control switch generates an output listing of the Richardson number, gas temperature, and gas volume concentration at each downwind distance.

   ISURF = Surface transfer code = 3. This model control switch specifies that no surface heat transfer is included by the model.

2. **Pool Data**

PPL = Source length = 4 m. Assuming a square dike, the pool length = pool width = 4 m.

PLHW = Source half-width = 2 m. This value is ½ of 4 m.

3. **Ambient Conditions**

Zo = Reference height = 10 m. This is the standard height for meteorological measurements.

Uo = Wind velocity at height Zo = 2 m/s. This value was obtained from on-site measurements.

AIRTEMP = Air temperature at ground level = 30°C.

RH = Relative humidity = 0.75. This value corresponds to 75% relative humidity.

TGROUND = Earth surface temperature = 30°C. This value was set equal to ambient temperature.

4. **DISPERSION**

ROUGH = Surface roughness parameter = 0.01 m. This value is typical of flat terrain covered by short grass.

MONIN = Monin-Obukhov length = 10,000. This value is obtained from Figure 1, page 22 of the user's guide for D stability.

CROSSW = Crosswind dispersion coefficients = 0.09158 (delta) and 0.905 (beta). The value of delta is derived from the conversion formula on page 21 of the user's guide for one hour average. These values are obtained from Table III-2 of the user's guide for D stability.

5. **CLOUD**

XSTEP = Output step length = 1.0. This model switch controls the downwind interval between rows of output data. The step length is a multiple of the source length (PLL). Thus, step length (1) times source length (4 m) = 4 m which is the reporting interval shown in output.

XMAX = Maximum calculated distance = 100. This is a number multiplied by the source length. Thus, 100 x 4 = 400 m. This indicates the distance at which execution and output are terminated.

CAMIN = Ground level centerline concentration at which calculation stops = 1×10^{-6} kg/m^3. This parameter is selected to be lower than the lower concentration limit (CL).

CU = Upper concentration limit = 1.5×10^{-5} kg/m^3. This value is chosen as a factor of 10 higher than CL.

CL = Lower concentration limit = 1.5×10^{-6} kg/m^3. This value is arbitrarily selected to provide isopleth information.

6. **SOURCE**

FLUX = Gas emission flux = 3.0×10^{-2} kg/m^2/s. This value is obtained from on-site estimates.

TEMPGAS = Temperature of emitted gas = -34.0°C. This is the boiling point temperature for chlorine. It is assumed that chlorine, stored as a liquid, flashed completely to vapor, (-239.1 K - 273.15 K = 34.0°C).

CPGAS = Heat capacity of emitted gas = 35.3 J/mole/°C. This value is obtained from chemical engineering handbook, (498.1 J/kg K x 1 mole/.0709 kg).

MWGAS = Molecular weight of emitted gas = 70.9 kg/k-mole. This value is obtained from a chemical engineering handbook.

WATGAS = Molar fraction picked up from water = 0. Since the spill occurs on land, no water transfer into the cloud occurs.

Model Output

The HEGADAS model output file is shown in Appendix C.2. The output file first shows a summary of model inputs. Some of the parameters listed were calculated directly by the model. The output lists the centerline concentration by distance from the source. The first two distances listed are within the source and are ignored. The third distance is at two source lengths away from the center of the source. The ground level concentration on plume axis at 100 m from the source is about 0.0039 kg/m^3. The last column provides the concentration percent volume (mole percent), which at 100 m is 0.138 volume percent. Multiply this value by 10^4 to convert to ppm results in 1380 ppm. The columns marked YCU and YCL tabulate the crosswind distance to the point at which the concentration is reduced to the "upper concentration limit" of 1.5×10^{-5} kg/m^3, and "lower concentration limit" of 1.5×10^{-6}. At 100 m downwind, these distances are about 57.5 m and 65.4 m, respectively.

Model output is terminated at 398 m. This is approximately equal to XMAX value (100) multiplied by PLL (4). At this point, the centerline concentration is 3.64×10^{-4} kg/m^3 or 128 ppm. The upper and lower concentration limits, 1.5×10^{-5} and 1.15×10^{-7} kg/m^3 are reached well beyond this distance. The user can re-run the model using a larger cut-off distance should there be a need to obtain the distances at those concentration levels.

3.3 SLAB Model

The SLAB model is capable of simulating a dense gas release from a ground level evaporating pool, an elevated horizontal jet, a stack or elevated vertical jet, or an instantaneous volume source. Sources may be part vapor and part liquid droplets; except the evaporating pool source which is assumed to be all vapor. The SLAB model summary description is shown in Appendix A.3. In applying the SLAB model, the user should follow the general modeling guidance criteria in Chapter 2. In addition, for some modeling scenarios, certain specific considerations may need to be made. These considerations are discussed below:

a. Temperature of the source material (K) - TS

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. For a pressurized jet release (IDSPL = 2 or 3), the source conditions are the properties of the material after it has fully expanded to atmospheric pressure. When the source material is stored as a vapor under pressure and, therefore released as a vapor (CMEDO = 0.0), the user's guide recommends that the expansion be treated as adiabatic and provides a formula for determining the source temperature. This equation appears to assume an adiabatic isentropic expansion. As explained in Section 2.5, the adiabatic isenthalpic expansion is more appropriate. Appendix E discusses how to make such a calculation.

b. Source area (m^2) - AS

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 using:

$$AS=\frac{QS}{RHOS.WS}$$

where QS is the input mass source rate, RHOS is the vapor density of the source material at the boiling point temperature, 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:

$$RHOS = (WMS \cdot P_a)/(R \cdot TBP)$$

where WMS is the input molecular weight of the source material, P_a is the ambient atmospheric pressure [P_a = 101325. N/m^2], R is the gas constant [R = 8.31431 J/(mol-K)]; and TBP is the input boing 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), the user's guide recommends that the expansion be treated adiabatically and the source area expressed as:

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

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

$$AS=\frac{RHOSL\cdot A_r}{\rho_{rel}}$$

where RHOSL is the input liquid density of the source material, A_r, is the actual area of the rupture or opening, and ρ_{rel} 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 is given by:

$$\rho_{rel} = 1/\left[\frac{(1 - CMEDO)}{RHOS} + \frac{CMEDO}{RHOSL}\right]$$

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. The user should refer to the SLAB model user's guide for additional detail.

c. Example Applications

SLAB Model Example 1: Continuous Chlorine Leak

In this hypothetical example, the SLAB model is used for planning purposes to simulate the release of chlorine gas from a pressurized tank through a 2.8 cm diameter hole. Chlorine is being stored as a gas in a large tank at ambient temperature under 6 atmospheres of pressure[5]. The hole is located 5m above ground and the release is directed upward. Chlorine forms a greenish-yellow gas with a characteristic, irritating odor. The NIOSH 15-minute exposure limit is 0.5 ppm. An estimate of the maximum off-site concentrations is desired. Additional parameters are: molecular weight = 70.9 g/g-mole; ambient temperature = 298 K; ratio of specific heats = 1.35; and relative humidity = 50 percent.

Using the approach suggested in Chapter 2, the user begins by using the procedure shown in the workbook and the TSCREEN model (EPA, 1990). This

[5]In this example, since chlorine is released as a gas and remain as a gas after depressurization, there is no need to consider any aerosol effects.

scenario is the same as Example 6.5 of the workbook. First, buoyancy and density are determined. The value for the Richardson number is well in excess of 30 indicating the need for a heavy gas model and the RVD screening model imbedded in TSCREEN is used to select the wind speed and Pasquill stability category for input into a refined dense gas model. The screening model results are reviewed to determine the maximum concentration at the facility fenceline (100m). This concentration occurs within stability classes E and F and 2 m/s wind speeds. The F stability and 2 m/s wind speed parameters are selected as input into the SLAB refined dense gas model.

The SLAB input file for this example is shown in Appendix C.3. The description of the input elements below is done line-by-line from what is shown in the input and output files. The user can refer to Section 3.1 "Input File" and Table 1 of the SLAB model user's guide for additional definition of terms.

1. **Line 1**

   IDSPL = Spill source type = 3. This indicates a vertical jet release.

2. **Line 2**

   NCALC = A switch that controls the number of substeps calculated by the code in integrating the system of equations from the source to the maximum downwind distance. Generally, a value of 1 is adequate.

3. **Line 3**

   WMS = Molecular weight of source material = 0.070906 kg/mole (chlorine). A convenient list for all the material properties required by SLAB for 14 chemicals is provided in Table 2 of the SLAB model user's guide.

4. **Line 4**

   CPS = Vapor heat capacity at constant pressure = 489.1 J/kg-K. This can be obtained from Table 2 in the SLAB model user's guide or other standard references.

5. **Line 5**

   TBP = Boiling point temperature = 239.1 K. This is obtained from Table 2 in the SLAB model user's guide.

6. **Line 6**

   CMEDO = Initial liquid mass fraction = 0. Since chlorine is released as a pure gas, there is no need to consider any aerosol releases due to phase change.

7. **Line 7**

   DHE = Heat of vaporization = 287840 J/kg. This is obtained from Table 2 in the SLAB model user's guide.

8. **Line 8**

   CPSL = Liquid heat capacity = 926.3 J/kg-K. This value is obtained from Table 2 in the SLAB model user's guide. See item 10 below.

9. **Line 9**

   RHOSL = Liquid density of source material = 1574.0 kg/m^3. This value is obtained from Table 2 in the SLAB model user's guide.

10. **Line 10**

    SPB = Saturation pressure constant = -1.0 (default value given in Table 1 of the SLAB user's guide). Since 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 appropriate; thus neither the saturation pressure constants nor any of the liquid properties will be used in the SLAB model calculations.

11. **Line 11**

SPC = Saturation pressure constant = -1.0 (default value given in Table 1 of the SLAB user's guide). See item 10 above.

12. **Line 12**

TS = Temperature of source material = 284.3 K. TS = Temperature of source material after expansion to atmospheric pressure. This parameter can be calculated according to the formulation given in Appendix E for an isenthalpic expansion.

13. **Line 13**

QS = Mass source rate = 1.261 kg/s. See page 6-14 of the workbook for details on how this value was calculated.

14. **Line 14**

AS = Source area = .003525 m^2. AS = $(P_{st}/P_a) \cdot (TS/T_{st}) \cdot A_r$ = $(6./1.) \cdot (284.3/298) \cdot (.000616)$ = .003525 m^2. The area of the rupture is .000616 m^2 and corresponds to a hole diameter of 2.8 cm.

15. **Line 15**

TSD = Continuous source duration = 25000 s. A steady-state release is appropriate when storage capacity of the system is much larger than the release rate. In addition, the applicability of a steady-state simulation depends also on advection or travel time to the lowest concentration of interest (t_{trav}) as discussed in Section 2.2. This step requires an examination of the output. At 10,000 m, the maximum centerline concentration is about 12.5 ppm. The distance to the 0.5 ppm is much further downwind, and probably as far as 25,000 m. Thus, $2(L_c/u) \approx 25{,}000$ sec.

16. **Line 16**

QTIS = Instantaneous source mass = 0. For a jet release, the user's guide specifies that this parameter should be set to zero.

17. **Line 17**

HS = Source height = 5 m.

18. **Line 18**

TAV = Concentration averaging time = 900 s (15 min.). This averaging time is assumed to pose a concern for public health. Note, the NIOSH Exposure Limit has 15-minute ceiling of .5 ppm.

19. **Line 19**

XFFM = Maximum downwind distance = 10,000 m.

20. **Line 20 thru 24**

ZP = Concentration measurement height = 0, 1, 2, and 4 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. If the concentration is desired at only N heights where N < 4, then set ZP(I), I = 1, N equal to the N desired heights and set ZP(I), I = N + 1, 4 equal to zero.

21. **Line 25**

ZO = Surface roughness height = 0.01 m. This value is typical of terrain covered by grass. See Table 2.1 and Table 3 in the SLAB model user's guide.

22. **Line 26**

ZA = Ambient measurement height = 10 m. This is the standard reference height for meteorological measurements.

23. **Line 27**

UA = Ambient wind speed = 2 m/s.

24. **Line 28**

TA = Ambient temperature = 298 K.

25. **Line 29**

RH = Relative humidity = 50 percent.

26. **Line 30**

STAB = Stability class values = 6. This is the Pasquill-Gifford F stability category.

27. **Line 31**

Input file closure = -1.0. This code signifies the end of the input file.

<u>Model Output</u>

The SLAB model output file is shown in Appendix C.3. In addition to the problem description, the output lists several other types of information. For example, the calculated vertical vapor velocity (ws) is 117.7 m/s. The instantaneous spatially averaged cloud parameters output gives intermediate results in that they do not include the effects of cloud meander or time-averaging. The output lists three sub-titles: 1) concentration parameters; 2) concentration in the z plane (up to 4 heights specified by the user); and 3) maximum centerline concentration. In the Z = 0 plane (Part 2), the column bbc shows the effective half width and the column y/bbc = 0 gives the centerline concentration. The concentration should be multiplied by one million (10^6) to convert to a ppm value. As can be seen, the maximum centerline concentration is 6.3×10^3 ppm at a downwind distance of 68.7 m. In the maximum centerline concentration portion of the output (Part 3), the user can see the maximum height of the plume centerline is 16.3 m, and that this height is reached between 10.5 m and 12.6 m downwind of the source.

SLAB Model Example 2: Ammonia Pipeline Rupture

The model is used here to assess the hazard extent of a past event which occurred at about 8:00 a.m. when a bulldozer struck and ruptured an 8-inch ammonia pipeline operating at approximately 700 psi. The rupture was estimated as 4 cm in diameter, and the release rate was estimated as 56 kg/s. The climatological data from the nearest NWS station were examined and the following meteorological record reconstructed for this event: wind speed = 4.5 m/s, ambient temperature = 298 K, atmospheric stability class = D, relative humidity = 50 percent, and atmospheric pressure = 0.98 atmospheres. The dense aerosol plume reportedly etched a parabolic-shaped scar about 6 miles long and 1/2 mile wide on surrounding vegetation. Ammonia is a colorless gas with a penetrating pungent, suffocating odor; it exits as a liquid under 700 psi pressure. The SLAB input file for this example is shown in Appendix C.3. The input parameters are described below.

1. **Line 1**

   IDSPL = Spill source type = 3. This indicates a vertical jet release.

2. **Line 2**

   NCALC = A switch that controls the number of substeps calculated by the code in integrating the system of equations from the source to the maximum downwind distance. Generally, a value of 1 is adequate.

3. **Line 3**

   WMS = Molecular weight of source material = 0.017031 kg/mole (ammonia). This is obtained from Table 2 in the SLAB user's guide.

4. **Line 4**

   CPS = Vapor heat capacity at constant pressure = 2170 J/kg-K. This is obtained from Table 2 in the SLAB model user's guide.

5. **Line 5**

TBP = Boiling point temperature = 239.72 K. This is obtained from Table 2 in the SLAB model user's guide.

6. **Line 6**

CMEDO = Initial liquid mass fraction = .82.

$$CMEDO = 1.-CPSL \cdot (T_{st}-TBP)/DHE =$$

$$1.-(4294.) \cdot (298-239.72)/1370840 = .82$$

This adiabatic flash calculation is obtained from the equation given in the SLAB model user's guide. The storage temperature T_{st} is 298 K and the remaining constants are material properties given in Table 2 of the user's guide.

7. **Line 7**

DHE = Heat of vaporization = 1370840 J/kg. This is obtained from Table 2 in the SLAB model user's guide.

8. **Line 8**

CPSL = Liquid heat capacity = 4294 J/kg-K. This value is obtained from Table 2 in the SLAB model user's guide.

9. **Line 9**

RHOSL = Liquid density of source material = 682.8 kg/m^3. This value is obtained from Table 2 in the SLAB model user's guide.

10. **Line 10**

SPB = Saturation pressure constant = 2132.52 K. This value is obtained from Table 2 in the SLAB model user's guide. Note, since release forms an aerosol, default value is not used.

11. **Line 11**

SPC = Saturation pressure constant = -32.98 K. This value is obtained from Table 2 in the SLAB model user's guide.

12. **Line 12**

TS = Temperature of source material = 239.72 K. In this example, ammonia gas is being stored as a liquid under pressure and is released as a liquid droplet-vapor mixture. Consequently, the source temperature TS is the boiling point temperature TBP = 239.72 K.

13. **Line 13**

QS = Mass source rate = 56 kg/s. See page 6-14 of the workbook for details on how this value can be calculated.

14. **Line 14**

AS = Source area = 0.179 m^2.

$$AS = (RHOSL/\rho_{rel}) \cdot A_r = (682.8/4.782) \cdot (.00126) = 0.179 m^2.$$

The area of the rupture is .0324 m^2 and corresponds to a pipeline diameter of 8 inches. The density of the liquid-vapor mixture ρm and the vapor density RHOS were calculated as follows:

$$RHOS = (WMS \cdot P_a)/(R \cdot TBP) = [(.017031) \cdot (101325.)]/$$

$$(8.31431) \cdot (239.72)] = .8658\ kg/m^3$$

$$\rho_{rel} = 1/\left[\frac{1-CMEDO}{RHOS}\right] + \left[\frac{CMEDO}{RHOSL}\right] = 1/\left[\frac{.18}{.8658} + \frac{.82}{682.8}\right] = 4.782\ kg/m^3$$

15. **Line 15**

TSD = Continuous source duration = 16,200 s. The release is assumed to have lasted 4.5 hours.

16. **Line 16**

QTIS = Instantaneous source mass = 0. For a jet release, the user's guide specifies that this parameter should be set to zero.

17. **Line 17**

HS = Source height = .2 m. This is equal to the pipeline diameter of 8 inches.

18. **Line 18**

TAV = Concentration averaging time = 3,600 s (1 hour). A 1-hr exposure concentration is used to compare with vegetation damage.

19. **Line 19**

XFFM = Maximum downwind distance = 10,000 m. Because of the magnitude of the spill, the plume effects are assumed to be important at a large distance from the spill.

20. **Line 20 thru 24**

ZP = Concentration measurement height = 0, 1, 2, and 4 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.

21. **Line 25**

ZO = Surface roughness height = 0.01m. This value is typical of terrain covered by grass. See Table 2.1 and Table 3 in the SLAB model user's guide.

22. **Line 26**

ZA = Ambient measurement height = 10 m. This is the standard reference height for meteorological measurements.

23. **Line 27**

UA = Ambient wind speed = 4.5 m/s.

24. **Line 28**

TA = Ambient temperature = 298 K.

25. **Line 29**

RH = Relative humidity = 50 percent.

26. **Line 30**

STAB = Stability class values = 4. This is the Pasquill-Gifford D stability category.

27. **Line 31**

Input file closure = -1.0. This code signifies the end of the input file.

Model Output

The SLAB model output file is shown in Appendix C.3. By looking at the concentration in the Z = 0 plane, one can see that the maximum ground level concentration is 3.45×10^4 ppm at 95.1 m downwind of the source. At 10 km downwind, the centerline concentration has dropped to 53.4 ppm. Concentrations at or above 1000 ppm extend downwind to about 1700 m. The maximum cloud height above ground (plume rise) is 16.8 m above ground which occurs between 5 and 6 m downwind.

Table 3-1

Types of Releases Considered by Dense Gas Models

Dense Gas Release Type	Model		
	DEGADIS	HEGADAS	SLAB
Evaporating pool	X	X	X
Horizontal jet			X
Vertical jet	X		X
Variable rate release	X	X	
Instantaneous volume source	X	X	X

4.0 Application to Non-Dense Gas Models

In this chapter, the general guidance considerations, developed in Chapter 2 are applied to specific non-dense gas models. Many of the EPA regulatory models (EPA, 1986) fit this category. However, models developed specifically for air toxics releases and that contain features unique to such sources are described in this chapter. At the present time, only the AFTOX model is discussed. Table 4-1 shows the types of releases considered by this non-dense gas model. The discussion begins with those specific input parameters that cannot be readily obtained from reviewing the user's guide. For this model, two example applications are provided. The present examples do not address all of the release types that can be addressed by this model. The examples show the user how every model input parameter was derived. Where applicable, the user is refered to screening procedures in the workbook to select some of the variables needed for input.

4.1 AFTOX Model

The AFTOX model (Version 3.1) (Kunkel, 1988) is an interactive, PC-based Gaussian model with a variable number of puff releases per minute based on wind speed and distance from source. Continuous releases are simulated as a series of puff releases. The AFTOX model summary description is shown in Appendix B.1. In applying AFTOX to some modeling scenarios, certain specific considerations may need to be made as discussed below:

a. Atmospheric Stability Considerations

AFTOX uses a continuous stability parameter ranging from 0.5 to 6 in place of the familiar discrete stability categories. For the F stability class, for example, the stability parameter ranges from 5 to 6. The stability parameter is calculated based on: (1) relating the Monin-Obukhov length and surface roughness to the Pasquill stability categories; or (2) if the standard deviation of the horizontal wind direction (Sigma-theta) is known, calculating the stability parameter using a modified sigma-theta approach. Table 3 in the user's guide relates the modified sigma theta method to stability class by giving a range of sigma-theta values for each stability class. However, in order to ensure the use of the maximum value in each stability class range, for example 6 for F stability, the user should rely on Equation 28 of the user's guide to compute the stability parameter. For F stability, the standard deviation of the horizontal wind direction must be equal to or less than 1.37 for a one hour time period. If this value (1.37) is entered in the AFTOX model, then the stability parameter is set to exactly 6.

b. Example Applications

Example 1. Continuous Liquid Spill from a Pipe

In this example, the AFTOX model is used for planning purposes to simulate the release of dimethylhydrazine liquid spill from a leak in an unpressurized transfer pipe. This chemical was stored at ambient pressure and temperature. Due to its low volatility, this substance will form a pool, which in this case is unconfined. The pool evaporation rate is assumed to reach a steady state after spreading such that the evaporation rate equals the pipe flow rate. Dimethylhydrazine is a fuming, colorless liquid carcinogen with a strong odor. An estimate of the maximum hourly concentration is needed. The minimum distance between the edge of the spill and the plant fenceline is 100 m. Note, this release is similar to Example 6.15 in the workbook (EPA, 1988). Although hydrazine vapor is denser than air, the release is passive and this chemical is in the AFTOX chemical data base library, further supporting that AFTOX is applicable to this release. Other variables are: contaminant molecular weight = 60.1 g/g-mole; liquid release rate = 78.6 g/s; spill pool area = 58.8 m^2, ambient temperature = 10°C, and relative humidity = 50 percent. The AFTOX input file is shown in Appendix D. The input parameters are described line-by-line from what is shown in the input/output file. The user can refer to page 21 of the AFTOX model user's guide for additional explanation of terms.

1. **Line 1:**

   Station Data = Hanscom AFB. Since the example did not specify the location of the release, one of four stations, for which meteorological data are in the AFTOX memory file, is selected. This input is used to set stability, surface roughness at the wind measurement site and wind measurement height.

2. **Line 2:**

   Date = 08-10-89. The model may use this input to calculate solar elevation data in order to calculate stability using a method based on Monin-Obukhov length.

3. **Line 3:**

   Time = 0300. The model also uses this input to determine stability. During nighttime hours, the model uses stable or neutral conditions. A 24-hour clock is used for time.

4. **Line 4:**

   Type of Release = Continuous.

5. **Line 5:**

   Chemical Data = Dimethylhydrazine. This chemical is included in the model's chemical data base library. The model automatically lists the other two lines associated with this statement (i.e., STEL and TWA).

6. **Line 6:**

   Temperature = Ambient air temperature = 10°C.

7. **Line 7:**

   Wind Direction = 270°. This value should be obtained from direct on-site measurements. Here a 270° value is arbitrarily selected. Wind direction is used to determine the direction towards which the plume is traveling and does not influence the magnitude of the concentrations. This information is important if impact on a certain geographic area is needed.

8. **Line 8:**

   Wind Speed = 1 m/s. This value is selected from Table 2-3 of the workbook as a conservative estimate for ground level releases.

9. **Line 9:**

   Time of Spill = Nighttime Spill. This information is given by the model based on the fact that computed solar angle is less than zero.

10. **Line 10:**

    Cloud Cover = 0 Eighths. This value should be obtained from on-site observation or nearest NWS station. Here, a clear sky is assumed. According to the Turner Classification scheme, cloud cover < 4/10 during nighttime with wind speed < 2 m/s is classified as stable.

11. **Line 11:**

Inversion Base Height = No Inversion. This parameter refers to upper level conditions up to 500 meters above the ground.

12. **Line 12:**

Atmospheric Stability Parameter = 6. This value is computed by the model based on information input by user about time of day, cloud cover, wind speed, and inversion height. Here the method for determining stability based on wind speed and solar insolation was used by the model.

13. **Line 13:**

Spill Site Roughness Length = 1 cm. This value is typical of flat terrain.

14. **Line 14:**

This is a Liquid Release. This statement is output by model based on information stored in the chemical data library file and the air temperature.

15. **Line 15:**

Emission Rate = 4.72 kg/min. This value is obtained from the given emission rate of 78.6 gm/s.

16. **Line 16:**

Chemical is Still Leaking. This information is input by the user based on on-site information. If the chemical is still leaking, the model assumes steady state conditions.

17. **Line 17:**

Pool Temperature = 10°C. Assume pool surface temperature is in equilibrium with ambient temperature.

18. **Line 18:**

Area of Spill = 59 m^2. This is an approximation to the calculated pool area of 58.8 m^2.

19. **Line 19:**

Evaporation Rate = 3.13 kg/min. This value is calculated directly by the model. In the workbook example, there is another equation for estimating evaporation but AFTOX does not allow the direct input for this parameter.

20. **Line 20:**

Concentration Averaging Time = 60 min. This value is selected in order to obtain the maximum hourly concentration at the fenceline.

21. **Line 21:**

Elapsed Time Since Start of Spill = 60 min. For continuous releases, a long time period of at least 60 minutes should be selected to represent steady state conditions. Note that had the model output been more extensive the method described in Section 2.2 would have been applicable.

22. **Line 22:**

Elevation = 0 m. This value specifies receptor elevation. Here, a ground level concentration is needed.

23. **Line 23:**

Downwind Distance = 100 m. This value is selected because it is the closest distance to the site boundary.

24. **Line 24:**

Crosswind Distance = 0 m. This value indicates that a centerline concentration is needed.

Model Output

AFTOX model output is shown in Appendix D. The output file is brief. It first lists a summary of model inputs and then gives the hourly concentration at the specified point. For computers with a graphical display device, AFTOX output can also include a graphical display of plume contours superimposed on a grid. (see Appendix in AFTOX model user's guide).

The hourly concentration predicted by AFTOX is 220.5 ppm, or 0.57 g/m^3. There are three station data files in AFTOX. Thus, different estimates would have been obtained from each of the other three meteorological stations due to the variations in the roughness length at the meteorological tower and the spill sites.

Example 2. Continuous Liquid Spill from a Tank

The AFTOX model is used to assess the hazard extent of a past event where dimethylhydrazine was released from a liquid spill from a leak in an unpressurized storage tank. This chemical was stored at ambient pressure and temperature. The spill occurred in a diked area of 2,500 m^2. The pool evaporation rate is assumed to reach a steady state after spreading such that the evaporation rate equals the liquid release rate. A review of onsite meteorological records shows that the release occurred during early morning hours when the wind speed was 1 m/s; atmospheric stability condition was F; atmospheric temperature was 10°C; and relative humidity was 50 percent. This chemical is a fuming, colorless liquid carcinogen with a strong odor. The minimum distance between the edge of the spill area and the plant fenceline is 100 m. Note, this release is similar to Example 6.16 in the workbook (EPA, 1988). Other given variables are: contaminant molecular weight = 60.1 g/g-mole; liquid release rate = 2,227 g/s; and spill pool area = 2,037 m^2.

The AFTOX input file is shown in Appendix D. The input parameters are described below. The user should also refer to page 21 of the AFTOX model user's guide for a more complete definition of terms.

1. **Line 1:**

   Station Data: Vandenberg AFB. Since the example did not specify the location of the release, one of four stations, for which meteorological data are in AFTOX memory file, is selected. This input is used to set stability, surface roughness at the wind measurement site and wind measurement height.

2. **Line 2:**

   Date = 08-02-89. The model may use this input to calculate solar elevation data in order to calculate stability using a method based on Monin-Obukhov length.

3. **Line 3:**

   Time = 0300. The model also uses this input to determine stability. During nighttime hours, the model uses stable or neutral conditions.

4. **Line 4:**

   Type of Release = Continuous.

5. **Line 5:**

   Chemical Data = Dimethylhydrazine. This chemical is included in the model's chemical data base library. The model automatically lists the other two lines associated with this statement (i.e., STEL and TWA).

6. **Line 6:**

   Temperature = Ambient air temperature = 10°C.

7. **Line 7:**

Wind Direction = 16°. This value should be obtained from direct on-site measurements. Here a 16° value is arbitrarily selected. Wind direction is used to determine the direction towards which the plume is traveling and does not influence the magnitude of the concentrations. This information is important if impact on a certain geographic area is needed.

8. **Line 8:**

Wind Speed = 1 m/s.

9. **Line 9:**

Standard Deviation of Wind Direction = 1.37 Deg. This value should be determined from on-site meteorological measurements. Here, a value of 1.37 is chosen so that the atmospheric stability class is set to 6 by the model.

10. **Line 10:**

Wind Averaging Time = 60 minutes. This value should be obtained from on-site information about the averaging time associated with collecting the sigma-theta data. EPA modeling guidance (EPA, 1986) recommends using an hourly average value for sigma-theta.

11. **Line 11:**

Time of Spill = Nighttime Spill. This information is given by the model based on the fact that computed solar angle is less than zero.

12. **Line 12:**

Cloud Cover = 0 Eighths. This value should be obtained from on-site observations or nearest NWS station. Here, a clear sky is assumed.

According to the Turner classification scheme, cloud cover < 4/10 during nighttime with wind speed < 2 m/s is classified as stable.

13. **Line 13:**

    Inversion Base Height = No Inversion. This parameter refers to upper level conditions up to 500 meters above the ground.

14. **Lines 14 and 15:**

    Horizontal, Vertical Stability Parameter = 6. This value is computed by the model based on information input by the user about standard deviation of wind direction. Here, the standard deviation sigma-theta method overrode the method for determining stability based on wind speed and solar insolation because of input of on-site sigma-theta data.

15. **Line 16:**

    Spill Site Roughness Length = 1 cm. This value should be determined from on-site data. Here, a value typical of flat terrain was used.

16. **Line 17:**

    This is a liquid release. This statement is output by the model based on the boiling point temperature of the chemical and the ambient temperature.

17. **Line 18:**

    Emission Rate = 133.62 kg/min. This value is obtained from the given emission rate of 2,227 g/s.

18. **Line 19:**

    Chemical is Still Leaking. This information is input by the user based on on-site information. If chemical is still leaking, the model assumes steady state conditions.

19. **Line 20:**

Pool Temperature = 10°C. Assume pool surface temperature is in equilibrium with ambient air temperature. This is an acceptable assumption for long, continuous release times.

20. **Line 21:**

Area of Spill = 2,037 m^2. This area of the evaporating pool is the smaller of the impoundment area (2,500 m^2) and the area at which evaporation across the pool equals flow into the pool (2,037 m^2). The pool area calculations are shown on page 6-50 of the workbook.

21. **Line 22:**

Evaporation Rate = 72.13 kg/min. This value is calculated directly by the model. In the workbook example, there is another equation for estimating evaporation but the AFTOX model does not allow the user to directly input this parameter.

22. **Line 23:**

Concentration Averaging Time = 60 min. This value is selected in order to obtain an hourly concentration at the fenceline.

23. **Line 24:**

Elapsed Time Since Start of Spill = 1,440 min. For continuous releases, a long time period of at least 60 minutes should be selected to represent steady state conditions. Note that had the model output been more extensive, the method described in Section 2.2 could have been used to set this variable.

24. **Line 25:**

Elevation = 0 m. This value specifies receptor elevation. Here, a ground level concentration is needed.

25. **Line 26:**

Downwind Distance = 100 m. This value is selected because it is the closest distance to the site boundary.

26. **Line 27:**

Crosswind Distance = 0 m. This value indicates that a centerline concentration is needed.

Model Output

AFTOX model output is shown in Appendix D. The output file first lists a summary of model inputs and then gives the hourly concentration at the specified point. For computers with a graphical display device, AFTOX output can also include a graphical display of plume contours superimposed on a grid. (See Appendix in AFTOX model user's guide).

The hourly concentration predicted by AFTOX is 7761 ppm or 20.05 ug/m^3. There are three other station data files in AFTOX. Thus, different estimates would have been obtained for each of the meteorological stations due to the variations in the roughness length at the meteorological tower and the spill sites.

Table 4-1

Types of Releases Considered by Non-Dense Gas Models

Release Type	Model AFTOX
Continuous gas	X
Instantaneous gas	X
Continuous liquid	X
Instantaneous liquid	X
Continuous buoyant gas released from stack	X

REFERENCES

Britter, R. E. and J. McQuaid, 1988. Workbook on the Dispersion of Dense Gases. HSE Contract Research Report No. 17/1988, Health and Safety Executive, Sheffield, England.

Center for Chemical Process Safety (CCPS), 1988. Workbook of Test Cases for Vapor Cloud Source Dispersion Models. CCPS/AIChE, 345 East 47th St., New York, NY.

Felder, R. M. and R. W. Rousseau, 1986. Elementary Principles of Chemical Processes. Second Edition, John Wiley & Sons.

Guinnup, D. E. and Q. T. Nguyen, 1991. A Sensitivity Study of the Modeling Results from Three Dense Gas Dispersion Models in the Simulation of a Release of Liquefied Methane: SLAB, HEGADAS, and DEGADIS. Seventh Joint Conference on Applications of Air Pollution Meteorology with AWMA. January 14-18, 1991, New Orleans, LA.

Hanna, S. R. and P. J. Drivas, 1987. Guidelines for Vapor Cloud Dispersion Modeling. CCPS/AIChE, 345 East 47th St., New York, NY.

Hanna, S., D. Strimaitis and J. Chang, 1990. Results of Hazard Response Model Evaluation Using Desert Tortoise (NH_3) and Goldfish (HF) Data Bases, Volume 1: Summary Report. Prepared for American Petroleum Institute, Washington, DC.

King, C. J., 1988. Separation Processes. Second Edition, McGraw-Hill Book Company, New York.

Kunkel, B. A., 1988. User's Guide for the Air Force Toxic Chemical Dispersion Model (AFTOX). AFG-TR-88-009. (ADA199096).

Perry, R. H. and D. Green, 1984. Perry's Chemical Engineer's Handbook. Sixth Edition, McGraw-Hill, New York.

Petersen, R. L., 1989. Surface Roughness Effects on Heavier-Than-Air Gas Dispersion. Sixth Joint Conference on Applications of Air Pollution Meteorology. Anaheim, CA. January 30 - February 3.

Pielke, R. A., 1984. Mesoscale Meteorological Modeling. Academic Press, Orlando.

U.S. Environmental Protection Agency, 1986. Guideline on Air Quality Models (Revised) and Supplement A (1987). EPA-450/4-78-027R. U.S. Environmental Protection Agency, Research Triangle Park, NC. 27711 (NTIS PB 86-245248).

U.S. Environmental Protection Agency, 1987. On-site Meteorological Program Guidance for Regulatory Modeling Applications. EPA-450/4-87-013. U.S. Environmental Protection Agency, Research Triangle Park, NC 27711. (NTIS PB 87-227542.

U.S. Environmental Protection Agency, 1988. A Workbook of Screening Techniques for Assessing Impacts of Toxic Air Pollutants. EPA-450/4-88-009. U.S. Environmental Protection Agency, Research Triangle Park, NC 27711. (NTIS PB 89-134349).

U.S. Environmental Protection Agency, 1989a. User's Guide for the DEGADIS 2.1 Dense Gas Dispersion Model. EPA-450/4-89-019. U.S. Environmental Protection Agency, Research Triangle Park, NC 27711. (NTIS PB 90-213893)

U.S. Environmental Protection Agency, 1989b. User's Guide for RVD 2.0 - A Relief Valve Discharge Screening Model. EPA-450/4-88-024. U.S. Environmental Protection Agency, Research Triangle Park, NC 27711. (NTIS PB 89-151070)

U.S. Environmental Protection Agency, 1990a. User's Guide to TSCREEN, a Model for Screening Toxic Air Pollutant Concentrations. EPA-450/4-89-013. U.S. Environmental Protection Agency, Research Triangle Park, NC. (NTIS PB 91-141820)

U.S. Environmental Protection Agency, 1990b. Evaluation of Dense Gas Simulation Models. EPA-450/4-90-018. U.S. Environmental Protection Agency, Research Triangle Park, NC.

Witlox, H. W. M., 1988. User's Guide for the HEGADAS Heavy Gas Dispersion Program. Shell Research Ltd. - Thornton Research Center, P. O. Box 1, Chester, England.

APPENDIX A

Dense Gas Model Summaries

Table of Contents

A.1 DENSE GAS DISPERSION (DEGADIS) MODEL SUMMARY

Reference: Environmental Protection Agency, 1989. User's Guide for the DEGADIS 2.1 Dense Gas Dispersion Model. EPA-450/4-89-019. U.S. Environmental Protection Agency, Research Triangle Park, NC 27711. (NTIS PB 90-213893).

Availability: The user's guide is available through NTIS. The FORTRAN source code for operation on a VAX or PC can be downloaded through the Support Center for Regulatory Air Models (SCRAM) Bulletin Board System, (919)-541-5742.

Abstract: DEGADIS 2.1 is a dispersion model that can be used to model the transport of toxic chemical releases into the atmosphere regardless of plume buoyancy. Its range of applicability includes: gases or aerosols; continuous, instantaneous, finite duration, and time-variant releases; ground-level, low-momentum area releases; ground-level or elevated upwardly-directed stack jet releases. The model simulates only one set of meteorological conditions, and therefore should not be considered applicable over time periods much longer than 1 or 2 hours. The simulations are carried out over flat, unobstructed terrain for which the characteristic surface roughness is not a significant fraction of the depth of the dispersion layer. For aerosol releases, the model does not characterize the density of the release; rather, the user must assess that independently prior to the simulation.

a. Recommendations for Use

DEGADIS should be used as a refined modeling approach to estimate spatial and temporal distribution of short-term atmospheric concentrations (1-hour or less averaging times) resulting from toxic chemical releases. It is especially useful in situations where negative buoyancy effects are suspected to be important and where screening estimates of atmospheric concentrations are above levels of concern.

b. Input Requirements

Data can be input directly from an external input file or by keyboard using an interactive program module. The model does not accept real-time meteorolgical data or convert units of input values. All chemical property data must be input by the user, i.e., they are not stored within the model.

Source data requirements are: emission rate, release area and release duration; emission chemical and physical properties (molecular weight, density vs concentration for situations when the ideal gas law does not hold (such as aerosol releases), and contaminant heat capacity in the case of a nonisothermal gas release); stack parameters (diameter, elevation above ground level, and temperature at release point).

Meteorological data requirements are: wind speed at some designated height above ground, stability, surface roughness, ambient temperature and pressure, relative humidity, and ground surface temperature (which in most cases can be adequately approximated by the ambient temperature).

Receptor data requirements are: averaging time of interest, above-ground height of receptors, and maximum distance between receptors (since this parameter is used only for nominal control of the output listing, it is of secondary importance). No indoor concentrations are calculated by the model.

c. Output

Printed output includes in tabular form:

- Listing of model input data.
- plume centerline elevation, mole fraction, concentration, density, and temperature at each downwind distance.
- sigma y and sigma z values at each downwind distance.
- off-centerline distances to 2 specified concentration values at a specified receptor height at each downwind distance (these values can be used to draw concentration isopleths after model execution).
- concentration vs time histories for finite-duration releases (if specified by user).

The output file is automatically saved and must be sent to the appropriate printer after program execution.

No easily-accessed computer-readable output is generated by the current version of the program.

No graphical output is generated by the current version of this program.

d. Type of Model

DEGADIS estimates plume rise (and fall) and dispersion for vertically-upward jet releases using mass and momentum balances with air entrainment based on laboratory and field-scale data. These balances assume Gaussian similarity profiles for velocity, density, and concentration within the jet. Ground-level, denser-than-air phenomena is treated using a power law concentration distribution profile in the vertical and a hybrid top hat-Gaussian concentration distribution profile in the horizontal. A power law specification is used for the vertical wind profile. Ground-level cloud slumping phenomena and air entrainment are based on laboratory measurements and field-scale observations.

e. Pollutant Types

Gases and aerosols, regardless of buoyancy. Pollutants are assumed to be non-reactive and non-depositing.

f. Source-Receptor Relationships

Only one source can be modeled at a time.

There is no limitation to the number of receptors; the downwind receptor distances are internally-calculated by the model. The DEGADIS calculation is carried out until the plume centerline concentration is one-half of the lowest concentration level specified by the user.

The model contains no submodels for source calculations or release characterization.

g. Plume Behavior

Jet/plume trajectory is estimated from mass and momentum balance equations. Surrounding terrain is assumed to be flat, and stack tip downwash, building wake effects, and fumigation are not treated.

h. Horizontal Winds

Constant logarithmic velocity profile which accounts for stability and surface roughness is used.

A wind speed profile exponent is determined from a least squares fit of the logarithmic profile from ground level to the wind speed reference height. Calm winds can be simulated for ground-level, low-momentum releases.

Along-wind dispersion of transient releases is treated using the methods of Colenbrander (1980) and Beals (1971).

i. Vertical Wind Speed

Not treated.

j. Horizontal Dispersion

When the plume centerline is above ground level, horizontal dispersion coefficients are based upon Turner (1969) and Slade (1968) with adjustments made for averaging time.

When the plume centerline is at ground level, horizontal dispersion also accounts for entrainment due to gravity currents (as appropriate) parameterized from laboratory experiments.

k. Vertical Dispersion

When the plume centerline is above ground level, vertical dispersion coefficients are based upon Turner (1969) and Slade (1968). Perfect ground reflection is applied.

In the ground-level dense-gas regime, vertical dispersion is also based upon results from laboratory experiments in density-stratified fluids.

l. Chemical Transformation

Not specifically treated.

m. Physical Removal

Not treated.

n. Evaluation Studies

Spicer, T. O. and J. A. Havens, 1986. Development of Vapor Dispersion Models for Nonneutrally Buoyant Gas Mixtures - Analysis of USAF/N_2O_4 Test Data. USAF Engineering and Services Laboratory, Final Report, ESL-TR-86-24.

Spicer, T. O. and J. A. Havens, 1988. Development of Vapor Dispersion Models for Nonneutrally Buoyant Gas Mixtures - Analysis of TFI/NH_3 Test Data. USAF Engineering and Services Laboratory, Final Report, ESL-TR-87-72.

Zapert, J. G., R. J. Londergan, and H. Thistle, 1991. Evaluation of Dense Gas Simulation Models. EPA-450/4-90-018. U.S. Environmental Protection Agency, Research Triangle Park, NC 27711.

o. Operating Information

The model requires either a VAX computer or a PC for its execution.

The model currently does not require supporting software other than a VAX FORTRAN compiler or a Microsoft FORTRAN compiler version 5.0 for a PC.

p. References

Beals, G. A. 1971. A Guide to Local Dispersion of Air Pollutants. Air Weather Service Technical Report 214.

Colenbrander, G. W., 1980. A Mathematical Model for the Transient Behavior of Dense Vapor Clouds. Third International Symposium on Loss Prevention and Safety Promotion in the Process Industries, Basel, Switzerland.

Slade, D. H., 1968. Meteorology and Atomic Energy. U.S. Atomic Energy Commission, NTIS No. TID-24190.

Turner, D. B., 1969. Workbook of Atmospheric Dispersion Estimates. PHS Publication No. 999-26. U.S. Environmental Protection Agency, Research Triangle Park, NC 27711.

U.S. Environmental Protection Agency, 1989. User's Guide for RVD 2.0 - A Relief Valve Discharge Screening Model. EPA-450/4-88-024. U.S. Environmental Protection Agency, Research Triangle Park, NC 27711. (NTIS PB 89-151070).

A.2 HEAVY GAS DISPERSION (HEGADAS) MODEL SUMMARY

Reference: Witlox, H.W.M., 1988. User's Guide for the HEGADAS Heavy Gas Dispersion Program. Shell Research Ltd.-Thornton Research Center, P.O. Box 1, Chester, England, CH1 3SH

Availability: The user's manual and computer code is available as PB 89-164552 from:

Computer Products
National Technical Information Service
U.S. Department of Commerce
5815 Port Royal Road
Springfield, VA 22161
Phone (703) 487-4650

Abstract: HEGADAS is a mathematical dispersion model that can be used to model ground level steady-state and transient releases of a dense toxic gas formed from area sources such as liquid pools or gas clouds formed directly from leaks in process equipment. The model simulates dispersion of the dense gas by combining the effects of initial gravitational spreading and downwind turbulent mixing. Particular emphasis is given to thermodynamic effects on dispersion, including surface heat transfer and water vapor transfer and condensation. The model simulates only one set of meteorological conditions per run, and therefore should not be considered applicable over time periods much longer than 1 hour. The simulations are carried out over flat, and unobstructed terrain. The model is capable of simulating dispersion for a continuous range of surface roughnesses. However, no indoor concentrations are calculated by the model.

a. Recommendations for Use

HEGADAS should be used as a refined modeling approach to estimate ambient concentrations and the area of exposure to concentrations above specified threshold values for releases from evaporative pools (both continuous and instantaneous). It is especially useful in situations where negative buoyancy effects are suspected to be important.

b. Input Requirements

Data are input directly from an external input file. The model is not set up to accept real-time meteorological data or convert units of input values. All chemical property data must be input by the user, i.e., they are not stored within the model.

Source data requirements are: gas emission flux; dimensions of gas source; emission chemical and physical properties (molecular weight, specific heat, and molar fraction picked-up water (molar ratio of water initially in gas to dry gas), temperature of release gas).

Meteorological data requirements are: ambient wind speed at designated height above ground, temperature, relative humidity, surface roughness, and surface temperature (which in most cases can be adequately approximated by the ambient temperature).

Output control requirements are: output step length (distance between the output downwind concentrations defined as ratio of initial downwind step length to the length of the secondary source which results from slumping effects), distance at which calculation is stopped (ratio of X-coordinate at which calculation stops, to secondary source length), concentration thresholds at which calculation is stopped, and upper and lower concentration limits.

c. Output

No graphical output is generated by the current version of this program. Also, the output is not easily accessible by other software to generate graphics or make statistical checks. The output printfile is automatically saved and must be sent to the appropriate printer by the user after program execution. Printed output includes in tabular form:

Listing of model input data;

Downwind distance from source center (x-coordinate);

Ground level concentration on plume axis (dry gas);

Vertical and cross-wind dispersion coefficients;

Y-coordinate (i.e. cross-wind distance to the plume axis) at which the ground level concentration equals upper and lower concentration limits;

Height (Z-coordinate) at which the cloud centerline concentration equals upper and lower concentration limits;

d. Type of Model

The steady-state version of HEGADAS assumes a hybrid top-hat/Gaussian similarity profile for concentration in the crosswind direction and a power law similarity profile in the vertical direction. This is accomplished by a solution to the differential equations for such parameters. The model estimates dispersion of the cloud by combining the effects of gravity spreading of gases and turbulent mixing. Gravity spread effects are included by defining effective variables for transport velocity, plume width resulting from the effects of gravity spreading and cloud heating.

e. Pollutant Types

Pollutants are assumed to be non-reactive and non-depositing dense gases. Surface heat transfer and water vapor flux are also included in the model.

f. Source-Receptor Relationships

Only one source can be modeled at a time.

There is no limitation to the number of receptors; the downwind receptor distances are internally-calculated by the model based on output control variables designated by user. The HEGADAS calculation is carried out until the plume centerline concentration meets the lowest concentration of interest specified by the user, or plume reaches the user specified distance.

The model contains no submodels for source calculations or release characterization.

g. Plume Behavior

Plume behavior is based on similarity profile relationships based on wind tunnel experiments. Surrounding terrain is assumed to be flat.

h. Horizontal Winds

A power law approximation of the constant logarithmic velocity profile which accounts for stability and surface roughness is used. In this power-law, the exponent is determined from a least squares fit of the logarithmic profile from ground level to twice the wind speed reference height.

i. Vertical Wind Speed

Not treated.

j. Horizontal Dispersion

The crosswind dispersion parameters are derived from a crosswind diffusion equation and a gravity-spreading equation. The first equation expresses the conservation of mass in the crosswind direction, and is based on experimental data by Turner (1969). The second equation describes the gravitational spreading due to the density difference between the vapor cloud and the surrounding air, and is based on experimental data by Van Ulden (1984). Along-wind dispersion of transient releases is treated using the methods of Colenbrander (1980).

k. Vertical Dispersion

The vertical dispersion coefficient is derived from an entrainment equation describing the entrainment of air in the gas cloud due to vertical mixing. This entrainment is assumed to be proportional to a function of a bulk Richardson number. This function describes the influence of the density stratification on the diffusion in the vertical direction and is obtained from wind tunnel and water channel experiments (McQuaid (1976) and Kranenburg (1984)).

l. Chemical Transformation

The thermodynamics of the mixing of the dense gas with ambient air are treated; however, any reactions of released chemicals with water are not treated unless the model is modified by the user.

m. Physical Removal

Not treated.

n. Evaluation Studies

Colenbrander, G.W., 1980. A Mathematical Model for The Transient Behaviour of Dense Gas Vapour Clouds, 3rd International Symposium on Loss Prevention and Safety Promotion in The Process Industries. Basel, September 1980.

Colenbrander, G.W. and J.S. Puttock, 1988. Description of The HEGADAS Model for Dispersion of Dense Gas Releases.

o. Operating Information

The model will operate on an IBM (AT, XT, and PS2 Model 50) and any other IBM-compatible PC. Minimum requirement for the program are 512K memory and PCDOS/MSDOS version 3.1 or higher. Use of a math coprocessor is highly recommended.

p. References

Kranenburg C., 1984. Wind-induced Entrainment in a Stably Stratified Fluid, J. Fluid Mech. 145, p. 253-273.

McQuaid, J., 1976. Some Experiments on the Structure of Stably-stratified Shear Flows. Technical Paper p. 21 Safety in Mines Research Establishment, Sheffield, U.K.

Turner, D.B., 1969. Workbook of Atmospheric Dispersion Estimates. U.S. Dept. of Health, Education and Welfare. Public Health Service Publication no. 999-AP-26.

Van Ulden, A.P., 1984. A New Bulk Model for Dense Gas Dispersion: Two-dimensional Spread in Still Air. In: Atmospheric Dispersion of Heavy Gases and Small Particles, (G. Ooms and H. Tennekes, eds.) pp. 419-440 Springer-Verlag, Berlin.

A.3 SLAB MODEL SUMMARY

Reference: Ermak, D.L., 1989. User's Manual for the SLAB model, An Atmospheric Dispersion Model for Denser-than-Air Releases, Draft, Lawrence Livermore National Laboratory.

Availability: Computer code and User's Manual can be obtained upon request from:

Donald L. Ermak, L-216
Atmospheric and Geophysical Sciences Division
Lawrence Livermore National Laboratory
P.O. Box 808
Livermore, CA 94550

Abstract: The SLAB model is a computer model, PC-based, that simulates the atmospheric dispersion of denser-than-air releases. The type of release treated by the model include ground-level evaporating pool, an elevated horizontal jet, a stack or elevated vertical jet and an instantaneous volume source. All sources except the evaporating pool may be characterized as aerosols. Only one type of release can be processed in an individual simulation. Also, the model simulates only one set of meteorological conditions; therefore direct application of the model over time periods longer than one or two hours is not recommended.

a. Recommendations for use

The SLAB model should be used as a refined model to estimate spatial and temporal distribution of short-term ambient concentration (e.g., 1-hour or less averaging times) and the expected area of exposure to concentrations above specified threshold values for toxic chemical releases where the release is suspected to be denser than the ambient air.

b. Input Requirements

The SLAB model is executed in the batch mode. Data are input directly from an external input file. There are 29 input parameters required to run the SLAB model. These parameters are divided into 5 categories by the user's guide: source type, source properties, spill properties, field properties, and meteorological parameters. The model is not designed to accept real-time meteorological data or convert units of input values. Chemical property data is not available within the model and must be input by the user. Some chemical and physical property data are available in the user's guide.

Source type is chosen as one of the following: evaporating pool release, horizontal jet release, vertical jet or stack release, or instantaneous or short-duration evaporating pool release.

Source property data requirements are physical and chemical properties (molecular weight, vapor heat capacity at constant pressure; boiling point; latent heat of vaporization; liquid heat capacity; liquid density; saturation pressure constants), and initial liquid mass fraction in the release.

Spill properties include: source temperature, emission rate, source dimensions, instantaneous source mass, release duration, and elevation above ground level.

Required field properties are: desired concentration averaging time, maximum downwind distance (to stop the calculation), and four separate heights at which the concentration calculations are to be made.

Meteorological parameter requirements are: ambient measurement height, ambient wind speed at designated ambient measurement height, ambient temperature, surface roughness, relative humidity, atmospheric stability class, and inverse Monin-Obukhov length (optional, only used as an input parameter when stability class is unknown).

c. Output

No graphical output is generated by the current version of this program. The output printfile is automatically saved and must be sent to the appropriate printer by the user after program execution. Printed output includes in tabular form:

Listing of model input data

Instantaneous spatially-averaged cloud parameters - time, downwind distance, magnitude of peak concentration, cloud dimensions (including length for puff-type simulations), volume (or mole) and mass fractions, downwind velocity, vapor mass fraction, density, temperature, cloud velocity, vapor fraction, water content, gravity flow velocities, and entrainment velocities;

Time-averaged cloud parameters - parameters which may be used externally to calculate time-averaged concentrations at any location within the simulation domain (tabulated as functions of downwind distance);

Time-averaged concentration values at plume centerline and at five off-centerline distances (off-centerline distances are multiples of the effective cloud half-width, which varies as a function of downwind distance) at four user-specified heights and at the height of the plume centerline.

d. Type of Model

Transport and dispersion are calculated by solving the conservation equations for mass, species, energy, and momentum, with the cloud being modeled as either a steady-state plume, a transient puff, or a combination of both depending on the duration of the release. In the steady-state plume mode, the crosswind-averaged conservation equations are solved and all variables depend only on the downwind distance. In the transient puff mode, the volume-averaged conservation equations are solved, and all variables depend only on the downwind travel time of the puff center of mass. Time is related to downwind distance by the height-averaged ambient wind speed. The basic conservation equations are solved via a numerical integration scheme in space and time.

e. Pollutant Types

Pollutants are assumed to be non-reactive and non-depositing dense gases or liquid-vapor mixtures (aerosols). Surface heat transfer and water vapor flux are also included in the model.

f. Source-Receptor Relationships

Only one source can be modeled at a time.
There is no limitation to the number of receptors; the downwind receptor distances are internally-calculated by the model. The SLAB calculation is carried out up to the user-specified maximum downwind distance.

The model contains submodels for the source characterization of evaporating pools, elevated vertical or horizontal jets, and instantaneous volume sources.

g. Plume Behavior

Plume trajectory and dispersion is based on crosswind-averaged mass, species, energy, and momentum balance equations. Surrounding terrain is assumed to be flat and of uniform surface roughness. No obstacle or building effects are taken into account.

h. Horizontal Winds

A power law approximation of the logarithmic velocity profile which accounts for stability and surface roughness is used.

i. Vertical Wind Speed

Not treated.

j. Vertical Dispersion

The crosswind dispersion parameters are calculated from formulas reported by Morgan, et al. (1983), which are based on experimental data from several sources. The formulas account for entrainment due to atmospheric turbulence, surface friction, thermal convection due to ground heating, differential motion between the air and the cloud, and damping due to stable density stratification within the cloud.

k. Horizontal Dispersion

The horizontal dispersion parameters are calculated from formulas similar to those described for vertical dispersion, also from the work of Morgan, et al. (1983).

l. Chemical Transformation

The thermodynamics of the mixing of the dense gas or aerosol with ambient air (including water vapor) are treated. The relationship between the vapor and liquid fractions within the cloud is treated using the local thermodynamic equilibrium approximation. Reactions of released chemicals with water or ambient air are not treated.

m. Physical Removal

Not treated.

n. Evaluation Studies

Blewitt, D. N., J. F. Yohn, and D. L. Ermak, 1987. An Evaluation of SLAB and DEGADIS Heavy Gas Dispersion Models Using the HF Spill Test Data, Proceedings, AIChE International Conference on Vapor Cloud Modeling, Boston, MA, November, pp. 56-80.

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. Haz. Matls., 6, pp. 129-160.

Zapert, J. G., R. J. Londergan, and H. Thistle, 1991. Evaluation of Dense Gas Simulation Models. EPA-450/4-90-018. U.S. Environmental Protection Agency, Research Triangle Park, NC 27711.

o. Operating Information

The model is written in standard FORTRAN 77 and operates on an IBM-compatible PC. Minimum requirements for the program are 512K memory and PCDOS/MSDOS version 3.1 or higher. Use of a math coprocessor will reduce simulation times.

p. References

Ermak, D. L., 1989. A Description of the SLAB Model, presented at JANNAF Safety and Environmental Protection Subcommittee Meeting, San Antonio, TX, April, 1989.

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.

APPENDIX B

Non-Dense Gas Model Summaries

Table of Contents

B.1 AIR FORCE TOXIC CHEMICAL DISPERSION (AFTOX) MODEL SUMMARY

Reference: Kunkel, B. A., 1988. User's Guide for the Air Force Toxic Chemical Dispersion Model (AFTOX). AFGL-TR-88-0009. (ADA199096)

Availability: Computer code and user's guide can be obtained upon request from:

Bruce A. Kunkel
Air Force Geophysics Laboratory (AFGL/LYA)
Hanscom AFB, MA 01731-5000
Telephone: (617) 377-2972

Abstract: AFTOX is an interactive, PC-based (for EGA and CGA systems), Gaussian puff model with a variable number of puff releases per minute based on wind speed and distance from source. The model is written in BASIC and was designed to compute concentrations from continuous or instantaneous, liquid or gas, elevated or surface, point or area source. AFTOX contains an additional subprogram for processing a buoyant plume from a stack. Only one type of release can be processed at a time and dense gas effects can not be modeled. Terrain is assumed to be flat. The model can 1) plot up to three concentration contours, 2) compute a concentration at a specified point and time, and 3) compute a maximum concentration at a given elevation and time. Some of the model's significant features include: 1) a stability parameter based on a continuous function, 2) use of roughness lengths, 3) variable averaging times from 1-minute to 1-hour, and 4) plot of a 90% probability hazardous area. There are 76 chemicals in its data base.

a. Recommendation for Use:

AFTOX is a refined modeling program for estimating concentrations from a continuous or instantaneous, liquid or gas, elevated or surface, point or area source in any kind of climatological location. The program is designed for chemical spills on flat terrain and is not applicable for complex terrain nor modeling dense gas effects. Only one set of meteorological data can be used each time the program is executed. Averaging times greater than 60 minutes are not recommended.

b. Input Requirements:

Two input files are used in AFTOX. The first file (SD.DAT) contains the meteorological site values which include: Site name, Latitude, Longitude, Roughness length, Wind instrument height above ground, Site elevation, and Greenwich Mean Time - local standard time zone difference.

The second file (CH.DAT) contains chemical data for 76 chemicals. The data include: Chemical name, time weighted averages, short-term emission levels, molecular weight, boiling point, critical temperature, critical pressure, critical volume, vapor pressure constants, liquid density constants, effective diameter of molecule, energy of molecular interaction.

A third file (CHEM.DAT) contains only the chemical names. If the chemical released is not on the list, the following chemical data are requested: Chemical name, molecular weight, vapor pressure.

Meteorological input includes: Ambient air temperature, wind direction and speed, wind direction standard deviation (optional), cloud cover, cloud height, wet/dry ground, snow cover, inversion base height, spill site roughness length.

For 'continuous' liquid or gaseous spills, input includes: emission rate through rupture, duration of spill, height of release (gas only), area of spill (liquid release only), pool temperature (liquid release only), and elapsed time since start of spill.

For 'instantaneous' liquid or gaseous releases, input includes: height of leak above ground (gaseous release only), total amount spilled, elapsed time since start of spill, pool temperature (liquid release only), area of spill (liquid release only).

For continuous buoyant release from a stack, input includes: molecular weight of effluent, emission rate per minute, stack height above ground level, gas stack exit temperature, volume flow rate of exit gas.

Other files exist for transferring data between parts of AFTOX.

c. Output

Three types of output can be generated by AFTOX. They are:

Maximum of three contour isopleth plot of concentrations;

Concentration at specific location and time; and

Maximum concentration at given elevation and time.

AFT.OUT is used to retain most of the input and output data. AFT.OUT is overwritten when AFTOX is reexecuted. If the data in AFT.OUT are needed, AFT.OUT should be renamed as soon as practical.

d. Type of Model

Technically, the model is a gaussian puff model. Mass conserving equations are used. A minimum of three puffs per minute are used to track and compute concentrations from continuous type sources. The faster the wind speed the more puffs per minute are required and used so there are no gaps between puffs. Stability classification is based upon Pasquill stability classes but instead of discrete classes, the classification system is a continuous function designed to avoid sudden changes in stability classes due to minor changes in input values.

e. Pollutant Types

AFTOX is capable of modeling non reactive gases and evaporating liquids but does not model dense gas effects.

f. Source-Receptor Relationships

AFTOX can be used to model a point or an area source but the main purpose of the model is to estimate a short-term concentration or an area where concentrations will be above a certain threshold. Terrain conditions such as dampness of the soil and whether the ground is snow covered are part of AFTOX input.

The program can produce a three level isopleth graph of concentration levels and/or predict the maximum concentration. The contours plotting starts at least 10 meters from the source. Maximum concentration predictions are calculated for as close as 30 meters from the source. Contour plots can extend outward to 100 km from the source.

There are an unlimited number of points at which concentrations can be calculated by AFTOX, but the receptor elevation, downwind and cross wind distances need to be entered each time a concentration is needed.

g. Plume Behavior

For continuous buoyant plumes, Briggs (1975) plume rise formula is used to calculate plume rise. All plumes are assumed to be neutral to positively buoyant. There is no building or stack tip downwash. Gradual plume rise is used.

From non stack sources, liquid spills are assumed to pool on the surface. The gaseous emission rate from an evaporating pool formed by a liquid spill is based on one of two convective mass transfer algorithms. These algorithms are selected internally by the model, as needed, based on the chemical information available in CH.DAT. The area of the pool is determined from an equilibrium established between the spillage and evaporation rates. An initial sigma value is determined based on the width of the pool.

h. Horizontal Winds

The measured wind speed height is adjusted by AFTOX to 10 m based on stability and roughness length at the meteorological site. The wind at the spill site is assumed to be equal to the computed wind at the meteorological site.

The wind direction is not adjusted. However, if there is a standard deviation of wind direction value available, that value is adjusted to a 60 minute averaging time and a 10 meter height.

i. Vertical Winds

Vertical winds are assumed to be zero.

j. Horizontal Dispersion

Two methods are available for calculating stability:

a. Wind, solar, roughness length and Monin-Obuhkov length values are used in conjunction with Golder's nomogram (1972) to determine a stability parameter.

b. The standard deviation of the wind direction is used to determine a stability parameter using the Modified Sigma Theta approach of Mitchell and Timbre (1979).

Stability parameters are a continuous form of the discrete values of the Pasquill Stability Classes and are used to derive dispersion values.

The Pasquill-Gifford dispersion parameters are used in this model and are adjusted for roughness length at the spill site and for the concentration averaging time.

A power law function is used to determine sigma y values using Hansen (1979) coefficients.

k. Vertical Dispersion

See Horizontal Dispersion concerning methods for calculating stability parameters.

A power law fit of Pasquill sigma-z curves is used and adjusted for roughness length and downwind distance.

Briggs (1975) plume rise equations are used for stack emissions.

Mixing height is entered manually.

Reflection terms are used only if there is an inversion below 500 meters. The terms are summed until the N-th term produces a value of less than 0.01.

Perfect reflection is assumed at the ground.

l. Chemical Transformations

Chemical transformations and decay are not modeled.

m. <u>Physical Removal</u>

There are no wet or dry deposition algorithms.

n. <u>Evaluations</u>

Kunkel, Bruce A., 1988. User's Guide to the Air Force Toxic Chemical Dispersion Model (AFTOX), Air Force Geophysics Laboratory Publication No. AFGL-TR-88-0009, EPR No. 992. Air Force Geophysics Laboratory, Hanscom AFB, MA 01731-5000. (ADA199096)

o. <u>Operating Information</u>

AFTOX runs interactively on an IBM-PC. The source code is not machine dependent and should be transferable to other computers running Basic.

The following two data files are mandatory and should be reviewed prior to running AFTOX: SD.DAT and CH.DAT.

The following three programs are accessory programs that allow the user to update and expand the above two data files or transfer plume plots from the screen to a printer.

SDFIL.EXE, CHFIL.EXE, and a graphics screen to printer program (i.e. MS-DOS's GRAPHICS command and compatible hardware).

p. <u>References</u>

Briggs, G. A. 1975. Plume Rise Predictions. Lectures on Air Pollution and Environmental Impact Analyses. American Meteorological Society, Boston, MA, pp. 59-111.

Golder, D., 1972. Relations between Stability Parameters in the Surface Layer. Boundary Layer Meteorology 3, 46-58.

Hansen, F. V., 1979. Engineering Estimates for the Calculation of Atmospheric Dispersion Coefficients. U.S. Army Atmospheric Science Laboratory, White Sands Missile Range, NM, Internal Report.

Mitchell, A. E., and K. O. Timbre, 1979. Atmospheric Stability Class from Horizontal Wind Fluctuation. Air Pollution Control Association Annual Meeting, Cincinnati, OH, paper 79-29.2.

Appendix C

Dense Gas Model Input and Output Files

Table of Contents

DEGADIS Example 1: Input File

```
Workbook scenario 6.5 - continuous leak of chlorine gas


2.0  10.                                 U0, Z0
0.01                                     ZR
1  6   0.                                INDVEL, ISTAB, RML
298.  1.  50.                            TAMB, PAMB, RELHUM
298.                                     TSURF
CL2                                      GASNAM
70.9                                     GASMW
900.                                     AVTIME - (15 min)
284.3                                    JETTEM
0.000005   0.000005   0.0                GASUL, GASLL, ZLL
0  500.  0.                              INDHT,  CPK, CPP
0                                        NDEN
1.261                                    ERATE
5.0  0.06701                             ELEJET, DIAJET
0.0                                      TEND
100.                                     DISTMX
```

Output File

```
********************          JETPLU/DEGADIS v2.1pc          ********************

31-JAN-1991  8:21: 8. 8

Workbook scenario 6.5 - continuous leak of chlorine gas



Ambient Meteorological Conditions...

Ambient windspeed at reference height:    2.0000      m/s
                     Reference height:    10.000      m
                    Surface roughness:   1.00000E-02 m

             Pasquill stability class:              F

                 Monin-Obukhov length:    11.821      m

                    Friction velocity:   6.43095E-02 m/s
                  Ambient temperature:   298.00      K
                     Ambient pressure:   1.0000      atm
                     Ambient humidity:   1.00920E-02
                    Relative humidity:   50.000      %

             Specified averaging time:   900.00      s
                               DELTAy:   7.30934E-02
                                BETAy:   .90000
                               DELTAz:   1.12200E-02
                                BETAz:   1.4024
                               GAMMAz:  -5.40000E-02


Contaminant Properties...

        Contaminant molecular weight:   70.910
                 Initial temperature:   284.30
              Upper level of interest:  5.00000E-06
              Lower level of interest:  5.00000E-07
              Heat capacity constant:   2155.0
                 Heat capacity power:   1.0000

NDEN flag:   0

ISOFL flag:   0


Release Properties...

                        Release rate:   1.2610     kg/s
                 Discharge elevation:   5.0000     m
                  Discharge diameter:  6.70100E-02 m
```

Model Parameters...

ALFA1: 2.80000E-02
ALFA2: .37000
DISTMX: 100.00 m

Downwind Distance (m)	Centerline Elevation (m)	Centerline Mole Fraction	Centerline Concentration (kg/m3)	Centerline Density (kg/m3)	Centerline Temperature (K)	Sigma y (m)	Sigma z (m)	At z = .000 m: Mole Fraction	At z = .000 m: Width to mol%: 5.00E-05 (m)	At z = .000 m: Width to mol%: 5.00E-04 (m)	Maximum Mole Fraction	Elevation for Max Mol Frac (m)
5.400E-07	5.52	1.00	3.04	3.04	284.	3.695E-02	3.699E-02	.000			1.00	5.52
52.3	18.4	4.359E-03	1.264E-02	1.19	298.	3.24	2.32	.000			4.359E-03	18.4
106.	14.1	1.519E-03	4.406E-03	1.18	298.	5.69	3.82	.000			1.519E-03	14.1
160.	9.25	7.499E-04	2.175E-03	1.18	298.	8.18	5.42	3.487E-04	17.6	17.6	7.500E-04	9.19
220.	3.66	6.795E-04	1.971E-03	1.18	298.	10.9	7.15	7.486E-04	23.4	23.4	7.486E-04	.000
261.	.000	6.353E-04	1.843E-03	1.18	298.	12.7	8.26	6.349E-04	27.3	27.3	6.353E-04	.000

0******************* U O A _ D E G A D I S M O D E L O U T P U T -- V E R S I O N 2.1 *******************

*************** *************** 31-JAN-1991 8:21:45.92 *************** ***************

Data input on 31-JAN-1991 8:21:42.96
Source program run on 31-JAN-1991 8:21:45.92

0 TITLE BLOCK

Workbook scenario 6.5 - continuous leak of chlorine gas

	Wind velocity at reference height		2.00	m/s
	Reference height		10.00	m
0	Surface roughness length		1.000E-02	m
0	Pasquill Stability class		F	
0	Monin-Obukhov length		11.8	m
	Gaussian distribution constants			
		Specified averaging time	900.00	s
		Deltay	.07309	
		Betay	.90000	
0	Wind velocity power law constant	Alpha	.34864	
	Friction velocity		.06431	m/s
0	Ambient Temperature		298.00	K
0	Surface Temperature		298.00	K
	Ambient Pressure		1.000	atm
	Ambient Absolute Humidity		1.009E-02	kg/kg BDA
	Ambient Relative Humidity		50.00	%

Adiabatic Mixing:	Mole fraction	CONCENTRATION OF C	GAS DENSITY	Enthalpy	Temperature
		kg/m**3	kg/m**3	J/kg	K
	.00000	.00000	1.17736	.00000	298.00
	.03634	.10560	1.24238	-582.25	297.40
	.09740	.28398	1.35227	-1438.5	296.41
	.16978	.49691	1.48332	-2294.7	295.28
	.25695	.75544	1.64226	-3151.0	293.95
	.36396	1.07578	1.83894	-4007.2	292.39
	.49846	1.48283	2.08849	-4863.5	290.51
	.67259	2.01672	2.41523	-5719.7	288.22
	.90691	2.74647	2.86091	-6576.0	285.37
	1.00000	3.03975	3.03975	-6850.0	284.30

0 Specified Gas Properties:

Molecular weight:	78.910	
Release temperature:	284.30	K
Density at release temperature and ambient pressure:	3.0397	kg/m**3
Average heat capacity:	500.00	J/kg K
Upper mole fraction contour:	5.00000E-06	
Lower mole fraction contour:	5.00000E-07	
Height for isopleths:	.00000	m

Source input data points

Initial mass in cloud: .00000

Time	Contaminant Mass Rate	Source Radius	Contaminant Mass Fraction	Temperature	Enthalpy
s	kg/s	m	kg contam/kg mix	K	J/kg
.00000	1.2610	27.279	1.56364E-03	297.99	-11.155
60230.	1.2610	27.279	1.56364E-03	297.99	-11.155
60231.	.00000	.00000	1.56364E-03	297.99	-11.155
60232.	.00000	.00000	1.56364E-03	297.99	-11.155

0 Calculation procedure for ALPHA: 1
0 Entrainment prescription for PHI: 3
0 Layer thickness ratio used for average depth: 2.1500
0 Air entrainment coefficient used: .590
0 Gravity slumping velocity coefficient used: 1.150
0 NON Isothermal calculation
0 Heat transfer calculated with correlation: 1
0 Water transfer not included

***** CALCULATED SOURCE PARAMETERS *****

Time sec	Gas Radius m	Height m	Qstar kg/m**2/s	SZ(x=L/2.) m	Mole frac C	Density kg/m**3	Temperature K	Rich No.
.000000	27.2792	1.100000E-05	1.005947E-04	3.04150	6.353376E-04	1.17841	297.989	.756144
13.6498	29.0547	3.00125	9.546420E-05	3.18950	6.023184E-04	1.17835	297.990	.756144
22.6908	30.9540	4.59421	9.068534E-05	3.34481	5.717093E-04	1.17830	297.990	.756144
49.3285	37.7437	7.58573	7.786986E-05	3.87746	4.904421E-04	1.17815	297.992	.756144
75.9663	45.0692	8.89250	6.880402E-05	4.41799	4.339412E-04	1.17805	297.993	.756144
127.054	58.8319	9.21671	5.872699E-05	5.35449	3.730674E-04	1.17794	297.994	.756144
178.141	71.5824	8.33037	5.383411E-05	6.14078	3.458992E-04	1.17789	297.994	.756144
238.518	85.1555	6.68965	5.160325E-05	6.89068	3.376697E-04	1.17788	297.994	.756144
271.122	89.7010	5.97245	5.163726E-05	7.11435	3.409199E-04	1.17788	297.994	.756144
487.196	86.5804	5.76447	5.444505E-05	6.89850	3.616724E-04	1.17792	297.994	.756144
811.717	84.9896	5.65847	5.556907E-05	6.76725	3.718664E-04	1.17794	297.994	.756144

0Source strength [kg/s] : 1.2610 Equivalent Primary source radius [m] : 27.279
Equivalent Primary source length [m] : 54.558 Equivalent Primary source half-width [m] : 21.425

Secondary source concentration [kg/m**3] : 1.07847E-03 Secondary source SZ [m] : 6.7673

Contaminant flux rate: 5.55691E-05

Secondary source mass fractions... contaminant: 9.155582E-04 air: .98910
Enthalpy: -6.1149 Density: 1.1779

Secondary source length [m] : 169.98 Secondary source half-width [m] : 66.751

0 Distance (m)	Mole Fraction	Concentration (kg/m**3)	Density (kg/m**3)	Gamma	Temperature (K)	Half Width (m)	Sz (m)	Sy (m)	Width at z= .00 m to: 5.000E-05mole% (m)	5.000E-04mole% (m)
346.	3.719E-04	1.078E-03	1.1779	.616	298.	66.8	6.77	1.762E-06	66.8	66.8
348.	3.699E-04	1.073E-03	1.1779	.616	298.	63.5	6.76	4.14	74.1	72.1
409.	3.276E-04	9.502E-04	1.1779	.616	298.	57.1	6.77	21.4	112.	101.
449.	2.995E-04	8.687E-04	1.1778	.616	298.	57.0	6.84	27.7	127.	113.
489.	2.747E-04	7.967E-04	1.1778	.616	298.	57.5	6.96	33.2	141.	124.
529.	2.519E-04	7.305E-04	1.1777	.615	298.	58.3	7.12	38.1	153.	134.
569.	2.311E-04	6.701E-04	1.1777	.615	298.	59.2	7.30	42.6	165.	143.
609.	2.122E-04	6.153E-04	1.1777	.615	298.	60.1	7.51	46.9	176.	151.
649.	1.951E-04	5.659E-04	1.1776	.615	298.	61.0	7.74	51.0	186.	159.
689.	1.797E-04	5.213E-04	1.1776	.615	298.	61.9	7.98	54.9	195.	166.
729.	1.659E-04	4.811E-04	1.1776	.615	298.	62.8	8.23	58.7	204.	173.
769.	1.534E-04	4.449E-04	1.1775	.615	298.	63.7	8.50	62.4	213.	179.
809.	1.422E-04	4.124E-04	1.1775	.615	298.	64.4	8.78	65.9	221.	185.
849.	1.321E-04	3.831E-04	1.1775	.615	298.	65.2	9.07	69.4	229.	191.
889.	1.229E-04	3.566E-04	1.1775	.615	298.	65.9	9.36	72.8	237.	196.
929.	1.147E-04	3.326E-04	1.1775	.616	298.	66.5	9.66	76.1	244.	201.
969.	1.072E-04	3.109E-04	1.1775	.616	298.	67.1	9.96	79.4	251.	206.

1.009E+03	1.004E-04	2.913E-04	1.1775	.616	298.	67.7	10.3	82.6	258.	211.
1.049E+03	9.426E-05	2.734E-04	1.1774	.609	298.	68.2	10.6	85.7	264.	215.
1.089E+03	8.864E-05	2.571E-04	1.1774	.616	298.	68.7	10.9	88.8	271.	219.
1.129E+03	8.350E-05	2.422E-04	1.1774	.615	298.	69.1	11.2	91.9	277.	223.
1.169E+03	7.880E-05	2.285E-04	1.1774	.615	298.	69.5	11.5	94.9	283.	227.
1.249E+03	7.054E-05	2.046E-04	1.1774	.613	298.	70.2	12.2	101.	294.	234.
1.289E+03	6.689E-05	1.940E-04	1.1774	.613	298.	70.5	12.5	104.	300.	237.
1.369E+03	6.042E-05	1.752E-04	1.1774	.611	298.	70.9	13.1	109.	310.	243.
1.409E+03	5.754E-05	1.669E-04	1.1774	.611	298.	71.1	13.5	112.	315.	246.
1.489E+03	5.239E-05	1.519E-04	1.1774	.611	298.	71.4	14.1	118.	325.	252.
1.529E+03	5.008E-05	1.452E-04	1.1774	.611	298.	71.5	14.5	120.	330.	254.
1.609E+03	4.592E-05	1.332E-04	1.1774	.610	298.	71.7	15.1	126.	339.	259.
1.649E+03	4.404E-05	1.277E-04	1.1774	.610	298.	71.7	15.4	128.	343.	261.
1.729E+03	4.063E-05	1.178E-04	1.1773	.610	298.	71.8	16.1	133.	351.	265.
1.769E+03	3.908E-05	1.133E-04	1.1773	.609	298.	71.7	16.4	136.	355.	267.
1.849E+03	3.625E-05	1.051E-04	1.1773	.609	298.	71.7	17.1	141.	363.	270.
1.889E+03	3.495E-05	1.014E-04	1.1773	.609	298.	71.6	17.4	143.	367.	272.
1.969E+03	3.258E-05	9.448E-05	1.1773	.608	298.	71.4	18.1	148.	375.	274.
2.009E+03	3.149E-05	9.132E-05	1.1773	.608	298.	71.3	18.4	151.	378.	276.
2.089E+03	2.948E-05	8.548E-05	1.1773	.608	298.	71.1	19.0	156.	385.	278.
2.129E+03	2.855E-05	8.279E-05	1.1773	.608	298.	70.9	19.3	158.	389.	279.
2.209E+03	2.682E-05	7.779E-05	1.1773	.607	298.	70.6	20.0	163.	395.	281.
2.249E+03	2.603E-05	7.548E-05	1.1773	.607	298.	70.4	20.3	165.	398.	282.
2.329E+03	2.454E-05	7.117E-05	1.1773	.607	298.	70.0	21.0	170.	405.	284.
2.409E+03	2.319E-05	6.725E-05	1.1773	.606	298.	69.6	21.6	174.	411.	285.
2.489E+03	2.195E-05	6.367E-05	1.1773	.606	298.	69.1	22.2	179.	417.	286.
2.569E+03	2.082E-05	6.039E-05	1.1773	.605	298.	68.6	22.9	183.	422.	287.
2.649E+03	1.979E-05	5.738E-05	1.1773	.605	298.	68.1	23.5	188.	428.	288.
2.729E+03	1.883E-05	5.461E-05	1.1773	.604	298.	67.5	24.1	192.	433.	288.
2.809E+03	1.795E-05	5.206E-05	1.1773	.604	298.	66.9	24.7	196.	438.	289.
2.889E+03	1.713E-05	4.969E-05	1.1773	.603	298.	66.3	25.4	201.	443.	289.
2.969E+03	1.638E-05	4.750E-05	1.1773	.603	298.	65.6	26.0	205.	448.	289.
3.049E+03	1.567E-05	4.546E-05	1.1773	.602	298.	65.0	26.6	209.	453.	288.
3.129E+03	1.502E-05	4.356E-05	1.1773	.602	298.	64.3	27.2	213.	457.	288.
3.209E+03	1.441E-05	4.179E-05	1.1773	.601	298.	63.6	27.8	217.	462.	287.
3.289E+03	1.384E-05	4.014E-05	1.1773	.601	298.	62.8	28.4	221.	466.	286.
3.369E+03	1.331E-05	3.859E-05	1.1773	.600	298.	62.1	29.0	225.	470.	285.
3.449E+03	1.281E-05	3.714E-05	1.1773	.600	298.	61.3	29.6	229.	474.	284.
3.529E+03	1.234E-05	3.578E-05	1.1773	.599	298.	60.5	30.2	233.	478.	282.
3.609E+03	1.189E-05	3.450E-05	1.1773	.599	298.	59.7	30.8	237.	482.	281.
3.689E+03	1.148E-05	3.329E-05	1.1773	.598	298.	58.9	31.4	241.	486.	279.
3.769E+03	1.109E-05	3.215E-05	1.1773	.598	298.	58.1	32.0	245.	490.	277.
3.849E+03	1.072E-05	3.108E-05	1.1773	.597	298.	57.3	32.6	249.	493.	275.

3.929E+03	1.037E-05	3.006E-05	1.1773	.597	298.	56.4	33.2	253.	497.	272.
4.009E+03	1.003E-05	2.910E-05	1.1773	.596	298.	55.5	33.8	257.	500.	270.
4.089E+03	9.720E-06	2.819E-05	1.1773	.596	298.	54.7	34.4	260.	503.	267.
4.169E+03	9.422E-06	2.733E-05	1.1773	.595	298.	53.8	34.9	264.	506.	264.
4.249E+03	9.139E-06	2.651E-05	1.1773	.595	298.	52.9	35.5	268.	509.	261.
4.329E+03	8.870E-06	2.573E-05	1.1773	.594	298.	52.0	36.1	272.	512.	258.
4.409E+03	8.614E-06	2.498E-05	1.1773	.593	298.	51.1	36.7	275.	515.	254.
4.489E+03	8.370E-06	2.428E-05	1.1773	.593	298.	50.1	37.2	279.	518.	250.
4.569E+03	8.137E-06	2.360E-05	1.1773	.592	298.	49.2	37.8	283.	521.	246.
4.649E+03	7.915E-06	2.296E-05	1.1773	.592	298.	48.3	38.4	286.	524.	242.
4.729E+03	7.703E-06	2.234E-05	1.1773	.591	298.	47.3	39.0	290.	526.	238.
4.809E+03	7.501E-06	2.175E-05	1.1773	.590	298.	46.4	39.5	293.	529.	233.
4.889E+03	7.307E-06	2.119E-05	1.1773	.590	298.	45.4	40.1	297.	532.	228.
4.969E+03	7.122E-06	2.065E-05	1.1773	.589	298.	44.4	40.6	300.	534.	223.
5.049E+03	6.944E-06	2.014E-05	1.1773	.589	298.	43.5	41.2	304.	536.	218.
5.129E+03	6.773E-06	1.964E-05	1.1773	.588	298.	42.5	41.8	307.	539.	212.
5.209E+03	6.610E-06	1.917E-05	1.1773	.587	298.	41.5	42.3	311.	541.	206.
5.289E+03	6.453E-06	1.872E-05	1.1773	.587	298.	40.5	42.9	314.	543.	199.
5.369E+03	6.302E-06	1.828E-05	1.1773	.586	298.	39.5	43.4	318.	545.	192.
5.449E+03	6.157E-06	1.786E-05	1.1773	.585	298.	38.5	44.0	321.	547.	185.
5.529E+03	6.018E-06	1.745E-05	1.1773	.585	298.	37.5	44.5	325.	549.	177.
5.609E+03	5.884E-06	1.706E-05	1.1773	.584	298.	36.5	45.1	328.	551.	169.
5.689E+03	5.754E-06	1.669E-05	1.1773	.583	298.	35.4	45.6	331.	553.	160.
5.769E+03	5.630E-06	1.633E-05	1.1773	.583	298.	34.4	46.2	335.	555.	150.
5.849E+03	5.510E-06	1.598E-05	1.1773	.582	298.	33.4	46.7	338.	557.	139.
5.929E+03	5.394E-06	1.564E-05	1.1773	.581	298.	32.4	47.2	341.	559.	126.
6.009E+03	5.282E-06	1.532E-05	1.1773	.581	298.	31.3	47.8	345.	560.	112.
6.089E+03	5.175E-06	1.501E-05	1.1773	.580	298.	30.3	48.3	348.	562.	94.8
6.169E+03	5.070E-06	1.471E-05	1.1773	.579	298.	29.2	48.8	351.	564.	70.8
6.249E+03	4.970E-06	1.441E-05	1.1773	.579	298.	28.2	49.4	354.	565.	
6.329E+03	4.872E-06	1.413E-05	1.1773	.578	298.	27.1	49.9	358.	567.	
6.409E+03	4.778E-06	1.386E-05	1.1773	.577	298.	26.1	50.4	361.	568.	
6.489E+03	4.687E-06	1.359E-05	1.1773	.577	298.	25.0	51.0	364.	570.	
6.569E+03	4.599E-06	1.334E-05	1.1773	.576	298.	24.0	51.5	367.	571.	
6.649E+03	4.513E-06	1.309E-05	1.1773	.575	298.	22.9	52.0	371.	572.	
6.729E+03	4.430E-06	1.285E-05	1.1773	.575	298.	21.8	52.6	374.	574.	
6.809E+03	4.350E-06	1.262E-05	1.1773	.574	298.	20.7	53.1	377.	575.	
6.889E+03	4.272E-06	1.239E-05	1.1773	.573	298.	19.7	53.6	380.	576.	
6.969E+03	4.197E-06	1.217E-05	1.1773	.572	298.	18.6	54.1	383.	577.	
7.049E+03	4.123E-06	1.196E-05	1.1773	.572	298.	17.5	54.6	386.	579.	
7.089E+03	4.088E-06	1.186E-05	1.1773	.571	298.	17.0	54.9	388.	579.	
7.169E+03	4.018E-06	1.165E-05	1.1773	.571	298.	15.9	55.4	391.	580.	
7.209E+03	3.983E-06	1.155E-05	1.1773	.570	298.	15.3	55.7	392.	581.	
7.289E+03	3.916E-06	1.136E-05	1.1773	.570	298.	14.3	56.2	396.	582.	

7.329E+03	3.883E-06	1.126E-05	1.1773	.569	298.	13.7	56.5	397.	582.
7.409E+03	3.819E-06	1.108E-05	1.1773	.568	298.	12.6	57.0	400.	583.
7.449E+03	3.788E-06	1.098E-05	1.1773	.568	298.	12.1	57.2	402.	584.
7.529E+03	3.726E-06	1.081E-05	1.1773	.567	298.	11.0	57.7	405.	585.
7.569E+03	3.696E-06	1.072E-05	1.1773	.567	298.	10.4	58.0	406.	585.
7.649E+03	3.637E-06	1.055E-05	1.1773	.566	298.	9.34	58.5	409.	586.
7.689E+03	3.608E-06	1.046E-05	1.1773	.566	298.	8.79	58.8	411.	586.
7.729E+03	3.579E-06	1.038E-05	1.1773	.565	298.	8.24	59.0	412.	587.
7.769E+03	3.551E-06	1.030E-05	1.1773	.565	298.	7.69	59.3	414.	587.
7.809E+03	3.523E-06	1.022E-05	1.1773	.565	298.	7.14	59.5	415.	588.
7.849E+03	3.495E-06	1.014E-05	1.1773	.564	298.	6.59	59.8	417.	588.
7.889E+03	3.468E-06	1.006E-05	1.1773	.564	298.	6.03	60.0	418.	588.
7.929E+03	3.442E-06	9.982E-06	1.1773	.564	298.	5.48	60.3	420.	589.
7.969E+03	3.415E-06	9.905E-06	1.1773	.563	298.	4.93	60.5	421.	589.
8.009E+03	3.389E-06	9.830E-06	1.1773	.563	298.	4.38	60.8	423.	589.
8.049E+03	3.363E-06	9.755E-06	1.1773	.562	298.	3.82	61.1	424.	590.
8.089E+03	3.338E-06	9.681E-06	1.1773	.562	298.	3.27	61.3	426.	590.
8.129E+03	3.313E-06	9.609E-06	1.1773	.562	298.	2.71	61.6	427.	590.
8.169E+03	3.288E-06	9.537E-06	1.1773	.561	298.	2.16	61.8	429.	591.
8.209E+03	3.264E-06	9.466E-06	1.1773	.561	298.	1.60	62.1	430.	591.
8.249E+03	3.240E-06	9.396E-06	1.1773	.560	298.	1.05	62.3	432.	591.
8.289E+03	3.216E-06	9.327E-06	1.1773	.560	298.	.492	62.6	433.	592.
8.325E+03	3.195E-06	9.267E-06	1.1773	.560	298.	.000	62.8	435.	592.
8.385E+03	3.144E-06	9.120E-06	1.1773	.559	298.	.000	63.3	437.	592.
8.505E+03	3.047E-06	8.836E-06	1.1773	.557	298.	.000	64.3	441.	593.
8.565E+03	2.999E-06	8.699E-06	1.1773	.556	298.	.000	64.8	443.	593.
8.685E+03	2.909E-06	8.436E-06	1.1773	.554	298.	.000	65.8	448.	594.
8.745E+03	2.865E-06	8.308E-06	1.1773	.553	298.	.000	66.3	450.	595.
8.865E+03	2.780E-06	8.063E-06	1.1773	.552	298.	.000	67.3	454.	595.
8.925E+03	2.739E-06	7.944E-06	1.1773	.551	298.	.000	67.8	457.	595.
9.045E+03	2.660E-06	7.715E-06	1.1773	.549	298.	.000	68.8	461.	596.
9.105E+03	2.622E-06	7.604E-06	1.1773	.548	298.	.000	69.3	463.	596.
9.225E+03	2.548E-06	7.389E-06	1.1773	.546	298.	.000	70.3	468.	597.
9.285E+03	2.512E-06	7.285E-06	1.1773	.545	298.	.000	70.8	470.	597.
9.405E+03	2.443E-06	7.085E-06	1.1773	.543	298.	.000	71.8	474.	597.
9.465E+03	2.409E-06	6.987E-06	1.1773	.542	298.	.000	72.3	476.	597.
9.585E+03	2.344E-06	6.799E-06	1.1773	.540	298.	.000	73.3	481.	598.
9.645E+03	2.313E-06	6.708E-06	1.1773	.539	298.	.000	73.8	483.	598.
9.765E+03	2.252E-06	6.531E-06	1.1773	.537	298.	.000	74.8	487.	598.
9.825E+03	2.222E-06	6.445E-06	1.1773	.536	298.	.000	75.3	489.	598.
9.945E+03	2.165E-06	6.278E-06	1.1773	.534	298.	.000	76.2	494.	598.
1.000E+04	2.137E-06	6.198E-06	1.1773	.533	298.	.000	76.7	496.	598.
1.012E+04	2.083E-06	6.041E-06	1.1773	.531	298.	.000	77.7	500.	598.

1.018E+04	2.057E-06	5.965E-06	1.1773	.530	298.	.000	78.2	502.	598.
1.030E+04	2.006E-06	5.817E-06	1.1773	.528	298.	.000	79.1	507.	597.
1.036E+04	1.981E-06	5.745E-06	1.1773	.527	298.	.000	79.6	509.	597.
1.048E+04	1.933E-06	5.606E-06	1.1773	.524	298.	.000	80.6	513.	597.
1.054E+04	1.909E-06	5.538E-06	1.1773	.523	298.	.000	81.0	515.	597.
1.066E+04	1.864E-06	5.406E-06	1.1773	.521	298.	.000	82.0	520.	596.
1.072E+04	1.842E-06	5.342E-06	1.1773	.520	298.	.000	82.5	522.	596.
1.084E+04	1.799E-06	5.217E-06	1.1773	.518	298.	.000	83.4	526.	596.
1.090E+04	1.778E-06	5.156E-06	1.1773	.517	298.	.000	83.9	528.	595.
1.102E+04	1.737E-06	5.038E-06	1.1773	.514	298.	.000	84.8	533.	595.
1.108E+04	1.717E-06	4.980E-06	1.1773	.513	298.	.000	85.3	535.	594.
1.120E+04	1.678E-06	4.868E-06	1.1773	.511	298.	.000	86.2	539.	593.
1.126E+04	1.660E-06	4.813E-06	1.1773	.510	298.	.000	86.7	541.	593.
1.138E+04	1.623E-06	4.707E-06	1.1773	.507	298.	.000	87.6	546.	592.
1.144E+04	1.605E-06	4.655E-06	1.1773	.506	298.	.000	88.1	548.	592.
1.156E+04	1.570E-06	4.554E-06	1.1773	.504	298.	.000	89.0	552.	591.
1.162E+04	1.553E-06	4.504E-06	1.1773	.503	298.	.000	89.5	554.	590.
1.174E+04	1.520E-06	4.408E-06	1.1773	.500	298.	.000	90.4	559.	589.
1.180E+04	1.504E-06	4.361E-06	1.1773	.499	298.	.000	90.9	561.	588.
1.192E+04	1.472E-06	4.269E-06	1.1773	.497	298.	.000	91.8	565.	587.
1.198E+04	1.466E-06	4.253E-06	1.1773	.496	298.	.000	92.3	567.	588.
1.210E+04	1.436E-06	4.165E-06	1.1773	.494	298.	.000	93.2	572.	587.
1.216E+04	1.421E-06	4.122E-06	1.1773	.492	298.	.000	93.6	574.	586.
1.228E+04	1.392E-06	4.038E-06	1.1773	.490	298.	.000	94.5	578.	585.
1.234E+04	1.378E-06	3.997E-06	1.1773	.489	298.	.000	95.0	580.	584.
1.246E+04	1.350E-06	3.917E-06	1.1773	.486	298.	.000	95.9	584.	582.
1.252E+04	1.337E-06	3.877E-06	1.1773	.485	298.	.000	96.4	586.	582.
1.264E+04	1.310E-06	3.801E-06	1.1773	.482	298.	.000	97.3	591.	580.
1.270E+04	1.298E-06	3.763E-06	1.1773	.481	298.	.000	97.7	593.	579.
1.282E+04	1.272E-06	3.690E-06	1.1773	.478	298.	.000	98.6	597.	577.
1.288E+04	1.260E-06	3.654E-06	1.1773	.477	298.	.000	99.1	599.	576.
1.300E+04	1.236E-06	3.584E-06	1.1773	.474	298.	.000	100.	604.	574.
1.306E+04	1.224E-06	3.550E-06	1.1773	.473	298.	.000	100.	606.	573.
1.318E+04	1.201E-06	3.483E-06	1.1773	.470	298.	.000	101.	610.	571.
1.324E+04	1.190E-06	3.450E-06	1.1773	.469	298.	.000	102.	612.	570.
1.336E+04	1.168E-06	3.386E-06	1.1773	.466	298.	.000	103.	616.	568.
1.342E+04	1.157E-06	3.355E-06	1.1773	.465	298.	.000	103.	618.	566.
1.354E+04	1.136E-06	3.294E-06	1.1773	.462	298.	.000	104.	623.	564.
1.360E+04	1.125E-06	3.263E-06	1.1773	.461	298.	.000	104.	625.	563.
1.372E+04	1.105E-06	3.205E-06	1.1773	.458	298.	.000	105.	629.	560.
1.378E+04	1.095E-06	3.176E-06	1.1773	.456	298.	.000	106.	631.	559.
1.390E+04	1.075E-06	3.119E-06	1.1773	.454	298.	.000	107.	635.	556.
1.396E+04	1.066E-06	3.092E-06	1.1773	.452	298.	.000	107.	638.	555.
1.408E+04	1.047E-06	3.037E-06	1.1773	.449	298.	.000	108.	642.	552.

1.414E+04	1.038E-06	3.011E-06	1.1773	.448	298.	.000	108.	644.	550.
1.426E+04	1.020E-06	2.959E-06	1.1773	.445	298.	.000	109.	648.	547.
1.432E+04	1.011E-06	2.933E-06	1.1773	.444	298.	.000	110.	650.	546.
1.444E+04	9.941E-07	2.883E-06	1.1773	.441	298.	.000	111.	654.	543.
1.450E+04	9.856E-07	2.859E-06	1.1773	.439	298.	.000	111.	657.	541.
1.462E+04	9.690E-07	2.810E-06	1.1773	.436	298.	.000	112.	661.	538.
1.468E+04	9.609E-07	2.787E-06	1.1773	.435	298.	.000	112.	663.	536.
1.480E+04	9.449E-07	2.740E-06	1.1773	.432	298.	.000	113.	667.	532.
1.486E+04	9.371E-07	2.718E-06	1.1773	.430	298.	.000	114.	669.	530.
1.498E+04	9.217E-07	2.673E-06	1.1773	.427	298.	.000	114.	673.	527.
1.504E+04	9.142E-07	2.651E-06	1.1773	.426	298.	.000	115.	675.	525.
1.516E+04	8.994E-07	2.608E-06	1.1773	.423	298.	.000	116.	680.	521.
1.522E+04	8.921E-07	2.587E-06	1.1773	.421	298.	.000	116.	682.	519.
1.534E+04	8.778E-07	2.546E-06	1.1773	.418	298.	.000	117.	686.	515.
1.540E+04	8.708E-07	2.526E-06	1.1773	.417	298.	.000	118.	688.	513.
1.552E+04	8.571E-07	2.486E-06	1.1773	.413	298.	.000	118.	692.	508.
1.558E+04	8.503E-07	2.466E-06	1.1773	.412	298.	.000	119.	694.	506.
1.570E+04	8.371E-07	2.428E-06	1.1773	.409	298.	.000	120.	699.	502.
1.576E+04	8.306E-07	2.409E-06	1.1773	.407	298.	.000	120.	701.	499.
1.588E+04	8.178E-07	2.372E-06	1.1773	.404	298.	.000	121.	705.	494.
1.594E+04	8.115E-07	2.354E-06	1.1773	.402	298.	.000	121.	707.	492.
1.606E+04	7.992E-07	2.318E-06	1.1773	.399	298.	.000	122.	711.	487.
1.612E+04	7.931E-07	2.300E-06	1.1773	.398	298.	.000	123.	713.	484.
1.624E+04	7.812E-07	2.266E-06	1.1773	.394	298.	.000	123.	717.	479.
1.630E+04	7.753E-07	2.249E-06	1.1773	.393	298.	.000	124.	720.	477.
1.642E+04	7.638E-07	2.215E-06	1.1773	.389	298.	.000	125.	724.	471.
1.648E+04	7.581E-07	2.199E-06	1.1773	.388	298.	.000	125.	726.	468.
1.660E+04	7.470E-07	2.167E-06	1.1773	.384	298.	.000	126.	730.	463.
1.666E+04	7.415E-07	2.151E-06	1.1773	.383	298.	.000	126.	732.	460.
1.678E+04	7.308E-07	2.120E-06	1.1773	.379	298.	.000	127.	736.	454.
1.684E+04	7.255E-07	2.104E-06	1.1773	.378	298.	.000	128.	738.	450.
1.696E+04	7.151E-07	2.074E-06	1.1773	.374	298.	.000	128.	742.	444.
1.702E+04	7.100E-07	2.059E-06	1.1773	.373	298.	.000	129.	745.	441.
1.714E+04	6.999E-07	2.030E-06	1.1773	.369	298.	.000	130.	749.	434.
1.720E+04	6.949E-07	2.016E-06	1.1773	.367	298.	.000	130.	751.	431.
1.732E+04	6.852E-07	1.987E-06	1.1773	.364	298.	.000	131.	755.	424.
1.738E+04	6.804E-07	1.973E-06	1.1773	.362	298.	.000	131.	757.	420.
1.750E+04	6.710E-07	1.946E-06	1.1773	.359	298.	.000	132.	761.	413.
1.756E+04	6.663E-07	1.932E-06	1.1773	.357	298.	.000	133.	763.	409.
1.768E+04	6.572E-07	1.906E-06	1.1773	.353	298.	.000	133.	767.	401.
1.774E+04	6.527E-07	1.893E-06	1.1773	.352	298.	.000	134.	769.	397.
1.786E+04	6.438E-07	1.867E-06	1.1773	.348	298.	.000	135.	774.	389.
1.792E+04	6.394E-07	1.855E-06	1.1773	.346	298.	.000	135.	776.	385.

1.804E+04	6.308E-07	1.830E-06	1.1773	.343	298.	.000	136.	780.	376.
1.810E+04	6.266E-07	1.817E-06	1.1773	.341	298.	.000	136.	782.	372.
1.822E+04	6.183E-07	1.793E-06	1.1773	.337	298.	.000	137.	786.	362.
1.828E+04	6.142E-07	1.781E-06	1.1773	.335	298.	.000	138.	788.	357.
1.840E+04	6.061E-07	1.758E-06	1.1773	.332	298.	.000	138.	792.	348.
1.846E+04	6.021E-07	1.746E-06	1.1773	.330	298.	.000	139.	794.	342.
1.858E+04	5.943E-07	1.724E-06	1.1773	.326	298.	.000	140.	798.	332.
1.864E+04	5.904E-07	1.712E-06	1.1773	.324	298.	.000	140.	800.	326.
1.876E+04	5.828E-07	1.690E-06	1.1773	.321	298.	.000	141.	805.	315.
1.882E+04	5.791E-07	1.679E-06	1.1773	.319	298.	.000	141.	807.	309.
1.894E+04	5.717E-07	1.658E-06	1.1773	.315	298.	.000	142.	811.	297.
1.900E+04	5.680E-07	1.647E-06	1.1773	.313	298.	.000	142.	813.	290.
1.912E+04	5.609E-07	1.627E-06	1.1773	.309	298.	.000	143.	817.	277.
1.918E+04	5.573E-07	1.616E-06	1.1773	.307	298.	.000	144.	819.	270.
1.930E+04	5.504E-07	1.596E-06	1.1773	.304	298.	.000	144.	823.	255.
1.936E+04	5.469E-07	1.586E-06	1.1773	.302	298.	.000	145.	825.	247.
1.948E+04	5.402E-07	1.567E-06	1.1773	.298	298.	.000	146.	829.	231.
1.954E+04	5.368E-07	1.557E-06	1.1773	.296	298.	.000	146.	831.	222.
1.966E+04	5.302E-07	1.538E-06	1.1773	.292	298.	.000	147.	835.	203.
1.972E+04	5.270E-07	1.528E-06	1.1773	.290	298.	.000	147.	838.	192.
1.984E+04	5.206E-07	1.510E-06	1.1773	.286	298.	.000	148.	842.	169.
1.990E+04	5.174E-07	1.501E-06	1.1773	.284	298.	.000	148.	844.	156.
2.002E+04	5.112E-07	1.483E-06	1.1773	.280	298.	.000	149.	848.	126.
2.008E+04	5.081E-07	1.474E-06	1.1773	.278	298.	.000	150.	850.	108.
2.020E+04	5.021E-07	1.456E-06	1.1773	.274	298.	.000	150.	854.	55.4
2.026E+04	4.991E-07	1.448E-06	1.1773	.272	298.	.000	151.	856.	
2.038E+04	4.932E-07	1.430E-06	1.1773	.268	298.	.000	152.	860.	
2.050E+04	4.874E-07	1.414E-06	1.1773	.264	298.	.000	152.	864.	

0

For the UFL of 5.00000E-04 mole percent, and the LFL of 5.00000E-05 mole percent:

The mass of contaminant between the UFL and LFL is: 3742.6 kg.
The mass of contaminant above the LFL is: 5877.4 kg.

```
Ammonia pipeline release (aerosol)


4.5  10.                                UO, ZO
0.01                                    ZR
1  4   0.                               INDVEL, ISTAB, RML
298. .98  50.                           TAMB, PAMB, RELHUM
298.                                    TSURF
NH3                                     GASNAM
17.0                                    GASMW
3600.                                   AVTIME - (1 hr)
239.72                                  TEMJET
0.001  0.0001  0.0                      GASULC, GASLLC, ZLL
0  0.0  0.0                             INDHT,  CPK, CPP
2                                       NDEN
0.0  0.0  1.154
1.0  4.782  4.782
56.                                     ERATE
0.0  0.478                              ELEJET, DIAJET
0.0                                     TEND
50.                                     DISTMX
```

Output File

```
********************          JETPLU/DEGADIS v2.1pc          ********************

31-JAN-1991  8:18:27. 4

Ammonia pipeline release (aerosol)



Ambient Meteorological Conditions...

Ambient windspeed at reference height:    4.5000      m/s
                    Reference height:    10.000      m
                   Surface roughness:   1.00000E-02  m

             Pasquill stability class:           D

                Monin-Obukhov length:     infinite

                  Friction velocity:    .22797      m/s
                Ambient temperature:    298.00      K
                   Ambient pressure:    .98000      atm
                   Ambient humidity:   1.03009E-02
                  Relative humidity:    50.000      %

          Specified averaging time:    3600.0      s
                             DELTAy:    .19461
                              BETAy:    .90000
                             DELTAz:   4.13400E-02
                              BETAz:    1.1737
                             GAMMAz:  -3.16000E-02


Contaminant Properties...

        Contaminant molecular weight:   17.000
                 Initial temperature:   239.72
             Upper level of interest:  1.00000E-03
             Lower level of interest:  1.00000E-04
              Heat capacity constant:  -33300.
                 Heat capacity power:   1.0000

NDEN flag:   2
 Mole fraction  Concentration     Density
                   (kg/m3)        (kg/m3)
    .00000         .00000         1.1537
    1.0000         4.7820         4.7820

ISOFL flag:   1


Release Properties...

                       Release rate:    56.000      kg/s
                Discharge elevation:   2.00000E-02  m
                 Discharge diameter:    .47800      m
```

Model Parameters...

```
ALFA1:   2.80000E-02
ALFA2:   .37000
DISTMX:  50.000     m
```

Downwind Distance (m)	Elevation (m)	Centerline Mole Fraction	Centerline Concentration (kg/m3)	Density (kg/m3)	Temperature (K)	Sigma y (m)	Sigma z (m)	At z = .000 m: Mole Fraction	Width to mol%: 1.00E-02 (m)	Width to mol%: 1.00E-01 (m)	Maximum Mole Fraction	Elevation for Max Mol Frac (m)
2.106E-07	3.70	1.00	4.78	4.78	298.	.264	.264	.000			1.00	3.70
26.9	25.3	.175	.141	1.26	298.	4.65	3.06	.000			.175	25.3
52.1	22.7	8.631E-02	6.352E-02	1.20	298.	7.54	4.13	.000			8.631E-02	22.7
78.4	18.6	4.600E-02	3.263E-02	1.18	298.	10.7	5.67	.000			4.600E-02	18.6
105.	14.5	2.843E-02	1.986E-02	1.17	298.	13.9	7.22	7.623E-03	29.9	28.1	2.843E-02	14.5
139.	9.67	1.970E-02	1.365E-02	1.16	298.	17.8	9.10	2.027E-02	38.3	38.3	2.049E-02	5.39
172.	5.43	2.016E-02	1:398E-02	1.16	298.	21.4	10.8	2.214E-02	46.0	46.0	2.214E-02	.000
199.	2.04	1.914E-02	1.326E-02	1.16	298.	24.4	12.1	1.940E-02	52.5	52.5	1.940E-02	.000
217.	.000	1.718E-02	1.188E-02	1.16	298.	26.3	12.9	1.717E-02	56.5	56.5	1.718E-02	.000

```
0*******************     U O A _ D E G A D I S   M O D E L   O U T P U T  - -  V E R S I O N  2.1     *******************

***************          *************** 31-JAN-1991  8:18:54.28 ***************          ***************

Data input on                 31-JAN-1991   8:18:51.15
Source program run on         31-JAN-1991   8:18:54.28

0        TITLE BLOCK

Ammonia pipeline release (aerosol)


     Wind velocity at reference height                   4.50   m/s
     Reference height                                    10.00   m
0    Surface roughness length                        1.000E-02   m
0    Pasquill Stability class                           D
0    Monin-Obukhov length                            infinite
     Gaussian distribution constants
                    Specified averaging time          3600.00   s
                                      Deltay            .19461
                                       Betay            .90000
0    Wind velocity power law constant  Alpha            .18667
     Friction velocity                                  .22797   m/s
0    Ambient Temperature                                298.00   K
     Ambient Pressure                                     .980   atm
     Ambient Absolute Humidity                       1.030E-02   kg/kg BDA
     Ambient Relative Humidity                           50.00   %

     Input:            Mole fraction    CONCENTRATION OF C      GAS DENSITY
                                            kg/m**3               kg/m**3
                          .00000            .00000               1.15367
                         1.00000           4.78200               4.78200
```

0 Specified Gas Properties:

Molecular weight:	17.000	
Release temperature:	239.72	K
Density at release temperature and ambient pressure:	4.7820	kg/m**3
Average heat capacity:	.00000	J/kg K
Upper mole fraction contour:	1.00000E-03	
Lower mole fraction contour:	1.00000E-04	
Height for isopleths:	.00000	m

Source input data points

Initial mass in cloud: .00000

Time	Contaminant Mass Rate	Source Radius	Contaminant Mass Fraction	Temperature	Enthalpy
s	kg/s	m	kg contam/kg mix	K	J/kg
.00000	56.000	56.500	1.02167E-02	298.00	.00000
60230.	56.000	56.500	1.02167E-02	298.00	.00000
60231.	.00000	.00000	1.02167E-02	298.00	.00000
60232.	.00000	.00000	1.02167E-02	298.00	.00000

0 Calculation procedure for ALPHA: 1
0 Entrainment prescription for PHI: 3
0 Layer thickness ratio used for average depth: 2.1500
0 Air entrainment coefficient used: .590
0 Gravity slumping velocity coefficient used: 1.150
0 Isothermal calculation
0 Heat transfer not included
0 Water transfer not included

***** CALCULATED SOURCE PARAMETERS *****

Time sec	Gas Radius m	Height m	Qstar kg/m**2/s	SZ(x=L/2.) m	Mole frac C	Density kg/m**3	Rich No.
.000000	56.5000	1.100000E-05	2.012786E-03	5.62223	1.717566E-02	1.16268	.756144
8.41086	59.2607	2.34979	1.940603E-03	5.84946	1.657970E-02	1.16237	.756144
28.4183	71.7098	5.74906	1.694975E-03	6.84128	1.457646E-02	1.16130	.756144
43.0972	82.2636	6.64112	1.557788E-03	7.64100	1.349147E-02	1.16073	.756144
69.2921	100.882	6.41580	1.413711E-03	8.95574	1.244771E-02	1.16018	.756144
95.4870	114.754	5.31354	1.370128E-03	9.83624	1.227937E-02	1.16009	.756144
121.543	114.241	5.28964	1.365813E-03	9.72826	1.234598E-02	1.16012	.756144

0Source strength [kg/s] : 56.000 Equivalent Primary source radius [m] : 56.500
Equivalent Primary source length [m] : 113.00 Equivalent Primary source half-width [m] : 44.375

Secondary source concentration [kg/m**3] : 8.50278E-03 Secondary source SZ [m] : 9.7283

Contaminant flux rate: 1.36581E-03

Secondary source mass fractions... contaminant: 7.329215E-03 air: .98255
Enthalpy: .00000 Density: 1.1601

Secondary source length [m] : 228.48 Secondary source half-width [m] : 89.725

0 Distance (m)	Mole Fraction	Concentration (kg/m**3)	Density (kg/m**3)	Temperature (K)	Half Width (m)	Sz (m)	Sy (m)	Width at z= .00 m to: 1.000E-02mole% (m)	.100 mole% (m)
331.	1.235E-02	8.503E-03	1.16	298.	89.7	9.73	.000	89.7	89.7
331.	1.233E-02	8.495E-03	1.16	298.	86.5	9.72	3.79	94.8	92.5
333.	1.230E-02	8.468E-03	1.16	298.	83.2	9.71	7.89	101.	95.7
355.	1.194E-02	8.224E-03	1.16	298.	72.1	9.57	25.5	128.	112.
395.	1.128E-02	7.760E-03	1.16	298.	65.1	9.39	42.2	157.	131.
435.	1.061E-02	7.300E-03	1.16	298.	61.6	9.31	54.7	180.	146.
475.	9.957E-03	6.844E-03	1.16	298.	59.5	9.31	65.4	200.	159.
515.	9.339E-03	6.415E-03	1.16	298.	58.0	9.36	75.0	218.	170.
555.	8.741E-03	6.001E-03	1.16	298.	57.0	9.46	84.0	235.	181.
595.	8.176E-03	5.610E-03	1.16	298.	56.2	9.60	92.5	250.	190.
635.	7.645E-03	5.244E-03	1.16	298.	55.5	9.78	101.	265.	199.
675.	7.150E-03	4.902E-03	1.16	298.	55.0	9.98	108.	279.	207.
715.	6.689E-03	4.584E-03	1.16	298.	54.5	10.2	116.	292.	214.
755.	6.262E-03	4.290E-03	1.16	298.	54.0	10.5	123.	305.	221.
795.	5.867E-03	4.018E-03	1.16	298.	53.6	10.7	130.	317.	227.
835.	5.503E-03	3.768E-03	1.16	298.	53.2	11.0	137.	328.	232.
875.	5.166E-03	3.536E-03	1.16	298.	52.7	11.3	144.	339.	237.
915.	4.856E-03	3.323E-03	1.16	298.	52.3	11.6	151.	349.	242.
955.	4.570E-03	3.127E-03	1.16	298.	51.8	12.0	157.	359.	246.
995.	4.306E-03	2.945E-03	1.16	298.	51.3	12.3	164.	369.	249.
1.035E+03	4.063E-03	2.778E-03	1.16	298.	50.9	12.6	170.	378.	252.
1.075E+03	3.838E-03	2.624E-03	1.16	298.	50.3	13.0	176.	387.	255.
1.155E+03	3.438E-03	2.350E-03	1.16	298.	49.2	13.7	188.	404.	259.
1.195E+03	3.260E-03	2.228E-03	1.16	298.	48.7	14.1	194.	412.	260.
1.275E+03	2.942E-03	2.010E-03	1.16	298.	47.4	14.8	206.	427.	262.
1.315E+03	2.799E-03	1.912E-03	1.16	298.	46.8	15.2	212.	434.	262.
1.395E+03	2.544E-03	1.737E-03	1.15	298.	45.4	16.0	223.	447.	261.
1.435E+03	2.428E-03	1.658E-03	1.15	298.	44.7	16.4	229.	454.	261.
1.515E+03	2.220E-03	1.516E-03	1.15	298.	43.2	17.2	240.	466.	258.
1.555E+03	2.126E-03	1.451E-03	1.15	298.	42.5	17.6	246.	472.	256.
1.635E+03	1.955E-03	1.334E-03	1.15	298.	40.9	18.4	256.	483.	251.
1.675E+03	1.877E-03	1.281E-03	1.15	298.	40.1	18.8	262.	488.	248.
1.755E+03	1.735E-03	1.184E-03	1.15	298.	38.4	19.7	272.	499.	241.
1.795E+03	1.670E-03	1.140E-03	1.15	298.	37.5	20.1	278.	503.	236.
1.875E+03	1.551E-03	1.058E-03	1.15	298.	35.7	20.9	288.	513.	227.
1.915E+03	1.496E-03	1.021E-03	1.15	298.	34.8	21.3	293.	517.	221.
1.995E+03	1.395E-03	9.520E-04	1.15	298.	33.0	22.2	303.	525.	208.

2.035E+03	1.349E-03	9.202E-04	1.15	298.	32.1	22.6	308.	529.	201.
2.115E+03	1.263E-03	8.614E-04	1.15	298.	30.1	23.4	318.	537.	184.
2.155E+03	1.223E-03	8.342E-04	1.15	298.	29.2	23.8	323.	541.	174.
2.235E+03	1.149E-03	7.836E-04	1.15	298.	27.2	24.7	333.	547.	151.
2.275E+03	1.114E-03	7.601E-04	1.15	298.	26.2	25.1	338.	551.	137.
2.355E+03	1.050E-03	7.163E-04	1.15	298.	24.2	26.0	347.	557.	101.
2.395E+03	1.020E-03	6.959E-04	1.15	298.	23.1	26.4	352.	560.	73.2
2.475E+03	9.644E-04	6.577E-04	1.15	298.	21.0	27.3	362.	566.	
2.515E+03	9.382E-04	6.398E-04	1.15	298.	20.0	27.7	366.	568.	
2.595E+03	8.891E-04	6.063E-04	1.15	298.	17.9	28.5	376.	573.	
2.635E+03	8.660E-04	5.906E-04	1.15	298.	16.8	29.0	380.	576.	
2.675E+03	8.439E-04	5.755E-04	1.15	298.	15.7	29.4	385.	578.	
2.715E+03	8.227E-04	5.610E-04	1.15	298.	14.6	29.8	390.	580.	
2.755E+03	8.023E-04	5.471E-04	1.15	298.	13.5	30.3	394.	582.	
2.795E+03	7.827E-04	5.337E-04	1.15	298.	12.4	30.7	399.	585.	
2.835E+03	7.639E-04	5.208E-04	1.15	298.	11.3	31.1	403.	586.	
2.875E+03	7.457E-04	5.085E-04	1.15	298.	10.2	31.5	408.	588.	
2.915E+03	7.283E-04	4.966E-04	1.15	298.	9.10	32.0	412.	590.	
2.955E+03	7.114E-04	4.851E-04	1.15	298.	7.98	32.4	417.	592.	
2.995E+03	6.952E-04	4.740E-04	1.15	298.	6.85	32.8	421.	594.	
3.035E+03	6.796E-04	4.634E-04	1.15	298.	5.72	33.2	426.	595.	
3.075E+03	6.645E-04	4.531E-04	1.15	298.	4.58	33.7	430.	597.	
3.115E+03	6.500E-04	4.432E-04	1.15	298.	3.44	34.1	435.	598.	
3.155E+03	6.360E-04	4.336E-04	1.15	298.	2.29	34.5	439.	599.	
3.195E+03	6.224E-04	4.243E-04	1.15	298.	1.14	35.0	443.	601.	
3.235E+03	6.095E-04	4.155E-04	1.15	298.	.000	35.4	448.	602.	
3.295E+03	5.822E-04	3.969E-04	1.15	298.	.000	36.3	454.	603.	
3.355E+03	5.568E-04	3.796E-04	1.15	298.	.000	37.3	461.	604.	
3.415E+03	5.330E-04	3.634E-04	1.15	298.	.000	38.2	467.	604.	
3.535E+03	4.899E-04	3.340E-04	1.15	298.	.000	40.1	480.	605.	
3.595E+03	4.703E-04	3.206E-04	1.15	298.	.000	41.0	487.	606.	
3.715E+03	4.345E-04	2.962E-04	1.15	298.	.000	42.9	500.	606.	
3.775E+03	4.182E-04	2.850E-04	1.15	298.	.000	43.8	506.	605.	
3.895E+03	3.881E-04	2.646E-04	1.15	298.	.000	45.7	519.	604.	
3.955E+03	3.744E-04	2.552E-04	1.15	298.	.000	46.6	525.	604.	
4.075E+03	3.489E-04	2.378E-04	1.15	298.	.000	48.5	538.	602.	
4.135E+03	3.372E-04	2.298E-04	1.15	298.	.000	49.4	545.	600.	
4.255E+03	3.154E-04	2.150E-04	1.15	298.	.000	51.3	557.	597.	
4.315E+03	3.053E-04	2.081E-04	1.15	298.	.000	52.2	564.	596.	
4.435E+03	2.865E-04	1.953E-04	1.15	298.	.000	54.0	576.	592.	
4.495E+03	2.778E-04	1.894E-04	1.15	298.	.000	54.9	583.	589.	
4.615E+03	2.615E-04	1.782E-04	1.15	298.	.000	56.8	595.	584.	
4.675E+03	2.539E-04	1.731E-04	1.15	298.	.000	57.7	602.	581.	
4.795E+03	2.397E-04	1.634E-04	1.15	298.	.000	59.5	614.	575.	

4.855E+03	2.330E-04	1.588E-04	1.15	298.	.000	60.4	621.	571.
4.975E+03	2.205E-04	1.503E-04	1.15	298.	.000	62.2	633.	563.
5.035E+03	2.146E-04	1.463E-04	1.15	298.	.000	63.1	640.	559.
5.155E+03	2.035E-04	1.387E-04	1.15	298.	.000	64.9	652.	550.
5.215E+03	1.983E-04	1.352E-04	1.15	298.	.000	65.9	658.	545.
5.335E+03	1.885E-04	1.285E-04	1.15	298.	.000	67.7	671.	534.
5.395E+03	1.838E-04	1.253E-04	1.15	298.	.000	68.6	677.	528.
5.515E+03	1.751E-04	1.193E-04	1.15	298.	.000	70.4	690.	516.
5.575E+03	1.709E-04	1.165E-04	1.15	298.	.000	71.2	696.	509.
5.695E+03	1.630E-04	1.111E-04	1.15	298.	.000	73.0	708.	495.
5.755E+03	1.593E-04	1.086E-04	1.15	298.	.000	73.9	715.	488.
5.875E+03	1.522E-04	1.037E-04	1.15	298.	.000	75.7	727.	471.
5.935E+03	1.488E-04	1.014E-04	1.15	298.	.000	76.6	733.	462.
6.055E+03	1.424E-04	9.708E-05	1.15	298.	.000	78.4	745.	443.
6.115E+03	1.394E-04	9.500E-05	1.15	298.	.000	79.3	752.	433.
6.235E+03	1.336E-04	9.105E-05	1.15	298.	.000	81.0	764.	411.
6.295E+03	1.308E-04	8.916E-05	1.15	298.	.000	81.9	770.	399.
6.415E+03	1.256E-04	8.557E-05	1.15	298.	.000	83.7	782.	373.
6.475E+03	1.230E-04	8.385E-05	1.15	298.	.000	84.6	789.	359.
6.595E+03	1,182E-04	8.057E-05	1.15	298.	.000	86.3	801.	328.
6.655E+03	1.159E-04	7.901E-05	1.15	298.	.000	87.2	807.	310.
6.775E+03	1.115E-04	7.601E-05	1.15	298.	.000	89.0	819.	271.
6.835E+03	1.094E-04	7.458E-05	1.15	298.	.000	89.9	825.	248.
6.955E+03	1.054E-04	7.183E-05	1.15	298.	.000	91.6	838.	192.
7.015E+03	1.035E-04	7.051E-05	1.15	298.	.000	92.5	844.	156.
7.135E+03	9.976E-05	6.798E-05	1.15	298.	.000	94.2	856.	
7.195E+03	9.798E-05	6.677E-05	1.15	298.	.000	95.1	862.	

0

For the UFL of .10000 mole percent, and the LFL of 1.00000E-02 mole percent:

The mass of contaminant between the UFL and LFL is: 34506. kg.
The mass of contaminant above the LFL is: 48163. kg.

HEGADAS Example 1: Input File

```
TITLE HEGADAS-S Workbook Example 6.15
     ICNT   =       0        *               CONTOURS OR CONTENTS CODE
    ISURF   =       3        *               SURFACE TRANSFER CODE
*                            *
POOL   DATA                  *
*                            *
   PLL      =  7.67          * M             SOURCE LENGTH
   PLHW     =  3.83          * M             SOURCE HALF-WIDTH
*                            *
AMBIENT CONDITIONS           *
*                            *
   Z0       =  10.0          * M             REFERENCE HEIGHT
   U0       =  1.5           * M/S           WIND VELOCITY AT HEIGHT Z0
   AIRTEMP  =  10.0          * DEG.CELSIUS   AIR TEMP. AT GROUND LEVEL
   RH       =  0.5           *               RELATIVE HUMIDITY
   TGROUND  =  10.0          * DEG.CELSIUS   EARTH-S SURFACE TEMPERATURE
*                            *
DISP                         *
*                            *
   ROUGH    =  0.01          * M             SURFACE ROUGHNESS PARAMETER
   MONIN    =  10.0          * M             MONIN - OBUKHOV LENGTH
   CROSSW   =  0.0705        * M**(1-BETA)   CROSSWIND (DELTA)
               0.902         *                         (BETA)
*                            *
CLOUD                        *
*                            *
   XSTEP    =  1.0           *               OUTPUT STEP LENGTH
   XMAX     =  100.          *               X AT WHICH CALC. IS STOPPED
   CAMIN    =  1.00E-07      * KG/M3         CA AT WHICH CALC. IS STOPPED
   CU       =  1.15E-06      * KG/M3         UPPER CONCENTRATION LIMIT
   CL       =  1.15E-07      * KG/M3         LOWER CONCENTRATION LIMIT
*                            *
SOURCE                       *
*                            *
   FLUX     =  1.34E-03      * KG/M2/S       GAS EMISSION FLUX
   TEMPGAS  =  10.0          * DEG.CELSIUS   TEMPERATURE  OF EMITTED GAS
   CPGAS    =  150.0         * J/MOLE/DEG.C  SPECIFIC HEAT OF EMITTED GAS
   MWGAS    =  60.1          * KG/KMOLE      MOL. WEIGHT OF EMITTED GAS
   WATGAS   =  0.            *               MOLAR FRACTION PICKED-UP WATE
*                            *
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Output File

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 CALCULATION CODE               ICNT =     0
 SURFACE HEAT TRANSFER MODEL   ISURF =     3
 THERMODYNAMIC MODEL         THERMOD = NORMAL
 SOURCE LENGTH                   PLL =   7.6700      M
 SOURCE HALF-WIDTH               PLW =   3.8300      M
 WIND VELOCITY AT HEIGHT Z0       U0 =   1.5000      M/S
 REFERENCE HEIGHT                 Z0 =   10.000      M
 SURFACE ROUGHNESS PARAMETER      ZR =  0.10000E-01 M
 AIR TEMP. AT GROUND LEVEL       TAP =   10.000      DEG.CELSIUS
 MONIN - OBUKHOV LENGTH        OBUKL =   10.000      M
                               DELTA =  0.70500E-01 M**(1-BETA)
                                BETA =  0.90200
 SPREADING CONSTANT               CE =   1.1500
 OUTPUT STEP LENGTH              DX0 =   1.0000
 X AT WHICH CALC. IS STOPPED    XMAX =   100.00
 CA AT WHICH CALC. IS STOPPED  CAMIN =  0.10000E-06 KG/M3
 UPPER CONCENTRATION LIMIT        CU =  0.11500E-05 KG/M3
 LOWER CONCENTRATION LIMIT        CL =  0.11500E-06 KG/M3
 EVAPORATION FLUX                  Q =  0.13400E-02 KG/M2/S =  0.78728E-01 KG/S
 RELATIVE HUMIDITY                 R =  0.50000
 TEMPERATURE   OF EMITTED GAS    TGE =   10.000      DEG.CELSIUS
 SPECIFIC HEAT OF EMITTED GAS    CPG =   150.00      J/MOLE/DEG.CELSIUS
 MOL. WEIGHT OF EMITTED GAS      FMG =   60.100      KG/KMOLE
 EARTH-S SURFACE TEMPERATURE    TW2P =   10.000      DEG.CELSIUS
 MOLAR FRACTION PICKED-UP WATER  W2P =  0.00000E+00
 HEAT GROUP IN HEAT FLUX QH   HEATGR =   24.000


 WIND PROFILE EXPONENT         ALPHA =  0.46507

                               USTAR =  0.44537E-01 M/S
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DISTANCE (M)	CA (KG/M3)	SZ (M)	SY (M)	MIDP (M)	YCU (M)	ZCU (M)	YCL (M)	ZCL (M)	RIB	TMP (DEG.C)	CONC (% VOL.)
-.384E+01	0.373E+00	0.00	0.00	3.83	3.83	0.00	3.83	0.00			
0.384E+01	0.373E+00	0.18	0.00	3.83	3.83	1.00	3.83	1.12	122.958	10.0	0.144E+02

TAKE-UP FLUX = 0.0013 KG/M2/S = 0.0787 KG/S

DISTANCE (M)	CA (KG/M3)	SZ (M)	SY (M)	MIDP (M)	YCU (M)	ZCU (M)	YCL (M)	ZCL (M)	RIB	TMP (DEG.C)	CONC (% VOL.)
0.115E+02	0.651E-01	0.19	3.44	17.08	28.45	0.96	29.59	1.09	23.018	10.0	0.252E+01
0.192E+02	0.203E-01	0.33	5.69	22.85	40.66	1.57	42.64	1.81	13.227	10.0	0.786E+00
0.268E+02	0.100E-01	0.48	7.59	26.17	49.05	2.15	51.78	2.51	10.058	10.0	0.388E+00
0.345E+02	0.616E-02	0.62	9.28	28.46	55.63	2.69	59.06	3.16	8.665	10.0	0.238E+00
0.422E+02	0.426E-02	0.75	10.81	30.17	61.16	3.18	65.23	3.76	7.996	10.0	0.165E+00
0.499E+02	0.318E-02	0.88	12.24	31.54	65.98	3.62	70.67	4.31	7.690	10.0	0.123E+00
0.575E+02	0.250E-02	1.00	13.58	32.66	70.30	4.03	75.57	4.82	7.589	10.0	0.966E-01
0.652E+02	0.204E-02	1.12	14.85	33.61	74.23	4.41	80.06	5.29	7.613	10.0	0.789E-01
0.729E+02	0.172E-02	1.22	16.06	34.43	77.86	4.75	84.23	5.73	7.719	10.0	0.663E-01
0.805E+02	0.147E-02	1.32	17.23	35.16	81.24	5.08	88.14	6.14	7.879	10.0	0.569E-01
0.882E+02	0.129E-02	1.42	18.35	35.80	84.43	5.38	91.84	6.53	8.076	10.0	0.497E-01
0.959E+02	0.114E-02	1.51	19.44	36.37	87.44	5.66	95.35	6.89	8.299	10.0	0.440E-01
0.104E+03	0.102E-02	1.60	20.50	36.90	90.30	5.92	98.70	7.23	8.542	10.0	0.394E-01
0.111E+03	0.923E-03	1.69	21.52	37.37	93.04	6.17	101.91	7.55	8.797	10.0	0.357E-01
0.119E+03	0.842E-03	1.77	22.52	37.81	95.66	6.41	105.00	7.86	9.061	10.0	0.325E-01
0.127E+03	0.773E-03	1.85	23.50	38.21	98.18	6.63	107.98	8.16	9.333	10.0	0.299E-01
0.134E+03	0.715E-03	1.92	24.46	38.58	100.61	6.85	110.86	8.44	9.610	10.0	0.276E-01
0.142E+03	0.664E-03	1.99	25.39	38.93	102.95	7.05	113.65	8.70	9.889	10.0	0.256E-01
0.150E+03	0.620E-03	2.06	26.31	39.25	105.23	7.24	116.36	8.96	10.171	10.0	0.239E-01
0.157E+03	0.581E-03	2.13	27.21	39.56	107.43	7.43	119.00	9.21	10.454	10.0	0.224E-01
0.165E+03	0.546E-03	2.20	28.09	39.84	109.58	7.61	121.57	9.45	10.737	10.0	0.211E-01
0.173E+03	0.515E-03	2.26	28.96	40.11	111.66	7.78	124.08	9.68	11.020	10.0	0.199E-01
0.180E+03	0.488E-03	2.32	29.82	40.36	113.69	7.94	126.53	9.90	11.303	10.0	0.188E-01
0.188E+03	0.463E-03	2.39	30.66	40.59	115.67	8.10	128.92	10.11	11.586	10.0	0.179E-01
0.196E+03	0.440E-03	2.44	31.49	40.81	117.61	8.26	131.26	10.32	11.867	10.0	0.170E-01
0.203E+03	0.420E-03	2.50	32.31	41.03	119.50	8.40	133.56	10.52	12.147	10.0	0.162E-01
0.211E+03	0.401E-03	2.56	33.12	41.22	121.35	8.55	135.81	10.72	12.426	10.0	0.155E-01
0.219E+03	0.384E-03	2.61	33.91	41.41	123.17	8.69	138.01	10.91	12.704	10.0	0.148E-01
0.226E+03	0.368E-03	2.67	34.70	41.59	124.94	8.82	140.18	11.09	12.979	10.0	0.142E-01
0.234E+03	0.354E-03	2.72	35.48	41.76	126.68	8.95	142.31	11.27	13.254	10.0	0.137E-01
0.242E+03	0.340E-03	2.77	36.25	41.93	128.39	9.08	144.41	11.45	13.528	10.0	0.131E-01
0.249E+03	0.328E-03	2.82	37.01	42.08	130.07	9.20	146.47	11.62	13.799	10.0	0.127E-01
0.257E+03	0.316E-03	2.87	37.77	42.23	131.72	9.32	148.50	11.79	14.070	10.0	0.122E-01
0.265E+03	0.305E-03	2.92	38.51	42.37	133.34	9.44	150.49	11.95	14.335	10.0	0.118E-01
0.272E+03	0.295E-03	2.97	39.25	42.50	134.94	9.55	152.46	12.11	14.605	10.0	0.114E-01
0.280E+03	0.285E-03	3.01	39.98	42.63	136.51	9.66	154.40	12.26	14.869	10.0	0.110E-01
0.288E+03	0.276E-03	3.06	40.70	42.75	138.05	9.77	156.32	12.42	15.132	10.0	0.107E-01
0.295E+03	0.268E-03	3.10	41.42	42.86	139.57	9.88	158.20	12.56	15.395	10.0	0.104E-01
0.303E+03	0.260E-03	3.15	42.13	42.97	141.07	9.98	160.07	12.71	15.655	10.0	0.100E-01

0.311E+03	0.253E-03	3.19	42.84	43.08	142.55	10.08	161.90	12.85	15.914	10.0	0.976E-02
0.318E+03	0.245E-03	3.24	43.54	43.18	144.01	10.18	163.72	12.99	16.171	10.0	0.948E-02
0.326E+03	0.239E-03	3.28	44.23	43.27	145.44	10.28	165.51	13.13	16.428	10.0	0.923E-02
0.334E+03	0.232E-03	3.32	44.92	43.36	146.86	10.37	167.29	13.27	16.681	10.0	0.898E-02
0.341E+03	0.226E-03	3.36	45.60	43.45	148.26	10.47	169.04	13.40	16.935	10.0	0.875E-02

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DISTANCE (M)	CA (KG/M3)	SZ (M)	SY (M)	MIDP (M)	YCU (M)	ZCU (M)	YCL (M)	ZCL (M)	RIB	TMP (DEG.C)	CONC (% VOL.)
0.349E+03	0.221E-03	3.40	46.28	43.53	149.64	10.56	170.77	13.53	17.186	10.0	0.853E-02
0.357E+03	0.215E-03	3.44	46.95	43.61	151.00	10.65	172.49	13.66	17.438	10.0	0.831E-02
0.364E+03	0.210E-03	3.48	47.62	43.69	152.35	10.73	174.18	13.78	17.686	10.0	0.811E-02
0.372E+03	0.205E-03	3.52	48.28	43.76	153.68	10.82	175.86	13.90	17.935	10.0	0.792E-02
0.380E+03	0.200E-03	3.56	48.94	43.83	155.00	10.90	177.52	14.03	18.181	10.0	0.774E-02
0.387E+03	0.196E-03	3.60	49.59	43.89	156.30	10.99	179.16	14.15	18.424	10.0	0.756E-02
0.395E+03	0.191E-03	3.63	50.24	43.95	157.58	11.07	180.79	14.26	18.668	10.0	0.740E-02
0.403E+03	0.187E-03	3.67	50.89	44.01	158.85	11.15	182.40	14.38	18.909	10.0	0.724E-02
0.410E+03	0.183E-03	3.71	51.53	44.07	160.11	11.23	183.99	14.49	19.152	10.0	0.708E-02
0.418E+03	0.180E-03	3.74	52.16	44.12	161.35	11.30	185.57	14.61	19.391	10.0	0.694E-02
0.426E+03	0.176E-03	3.78	52.80	44.17	162.58	11.38	187.14	14.72	19.630	10.0	0.679E-02
0.433E+03	0.172E-03	3.81	53.43	44.22	163.80	11.45	188.69	14.83	19.868	10.0	0.666E-02
0.441E+03	0.169E-03	3.85	54.05	44.26	165.01	11.53	190.23	14.93	20.103	10.0	0.653E-02
0.449E+03	0.166E-03	3.88	54.68	44.31	166.20	11.60	191.76	15.04	20.340	10.0	0.640E-02
0.456E+03	0.163E-03	3.92	55.29	44.35	167.38	11.67	193.27	15.14	20.574	10.0	0.628E-02
0.464E+03	0.160E-03	3.95	55.91	44.39	168.55	11.74	194.77	15.25	20.807	10.0	0.616E-02
0.472E+03	0.157E-03	3.98	56.52	44.42	169.71	11.81	196.26	15.35	21.038	10.0	0.605E-02
0.479E+03	0.154E-03	4.02	57.13	44.45	170.86	11.88	197.73	15.45	21.269	10.0	0.594E-02
0.487E+03	0.151E-03	4.05	57.73	44.49	172.00	11.94	199.19	15.55	21.500	10.0	0.584E-02
0.495E+03	0.148E-03	4.08	58.34	44.51	173.13	12.01	200.65	15.65	21.729	10.0	0.574E-02
0.502E+03	0.146E-03	4.11	58.94	44.54	174.24	12.07	202.09	15.74	21.957	10.0	0.564E-02
0.510E+03	0.143E-03	4.14	59.53	44.57	175.35	12.14	203.52	15.84	22.182	10.0	0.554E-02
0.518E+03	0.141E-03	4.18	60.13	44.59	176.45	12.20	204.94	15.93	22.409	10.0	0.545E-02
0.525E+03	0.139E-03	4.21	60.72	44.61	177.54	12.26	206.35	16.03	22.634	10.0	0.536E-02
0.533E+03	0.137E-03	4.24	61.30	44.63	178.62	12.32	207.74	16.12	22.858	10.0	0.528E-02
0.541E+03	0.134E-03	4.27	61.89	44.65	179.69	12.38	209.13	16.21	23.079	10.0	0.519E-02
0.548E+03	0.132E-03	4.30	62.47	44.67	180.75	12.44	210.51	16.30	23.302	10.0	0.511E-02
0.556E+03	0.130E-03	4.33	63.05	44.68	181.80	12.50	211.88	16.39	23.524	10.0	0.503E-02
0.564E+03	0.128E-03	4.36	63.63	44.69	182.85	12.56	213.24	16.48	23.744	10.0	0.496E-02
0.571E+03	0.126E-03	4.39	64.20	44.71	183.88	12.62	214.59	16.57	23.964	10.0	0.488E-02
0.579E+03	0.125E-03	4.42	64.77	44.72	184.91	12.68	215.93	16.65	24.184	10.0	0.481E-02
0.587E+03	0.123E-03	4.45	65.34	44.72	185.93	12.73	217.26	16.74	24.402	10.0	0.474E-02
0.594E+03	0.121E-03	4.48	65.91	44.73	186.94	12.79	218.59	16.82	24.617	10.0	0.467E-02
0.602E+03	0.119E-03	4.50	66.47	44.74	187.95	12.84	219.90	16.91	24.833	10.0	0.461E-02
0.610E+03	0.118E-03	4.53	67.03	44.74	188.94	12.90	221.21	16.99	25.051	10.0	0.454E-02
0.617E+03	0.116E-03	4.56	67.59	44.74	189.93	12.95	222.51	17.07	25.265	10.0	0.448E-02
0.625E+03	0.114E-03	4.59	68.15	44.75	190.92	13.00	223.80	17.15	25.477	10.0	0.442E-02
0.633E+03	0.113E-03	4.62	68.71	44.75	191.89	13.05	225.08	17.23	25.691	10.0	0.436E-02
0.640E+03	0.111E-03	4.64	69.26	44.75	192.86	13.11	226.36	17.31	25.904	10.0	0.430E-02
0.648E+03	0.110E-03	4.67	69.81	44.74	193.82	13.16	227.63	17.39	26.116	10.0	0.425E-02
0.656E+03	0.109E-03	4.70	70.36	44.74	194.78	13.21	228.89	17.47	26.327	10.0	0.419E-02
0.663E+03	0.107E-03	4.72	70.91	44.74	195.72	13.26	230.14	17.55	26.537	10.0	0.414E-02
0.671E+03	0.106E-03	4.75	71.45	44.73	196.67	13.31	231.38	17.62	26.746	10.0	0.409E-02
0.679E+03	0.104E-03	4.78	71.99	44.72	197.60	13.36	232.62	17.70	26.956	10.0	0.404E-02
0.686E+03	0.103E-03	4.80	72.54	44.72	198.53	13.40	233.85	17.78	27.163	10.0	0.399E-02
0.694E+03	0.102E-03	4.83	73.07	44.71	199.45	13.45	235.08	17.85	27.371	10.0	0.394E-02
0.702E+03	0.101E-03	4.86	73.61	44.70	200.37	13.50	236.30	17.92	27.576	10.0	0.389E-02
0.709E+03	0.995E-04	4.88	74.15	44.69	201.28	13.55	237.51	18.00	27.783	10.0	0.384E-02
0.717E+03	0.983E-04	4.91	74.68	44.67	202.19	13.59	238.71	18.07	27.988	10.0	0.380E-02

1HSMAIN HEGADAS-S PROGRAM (VERSION AUG88) PAGE
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<<<< HEGADAS-S Workbook Example 6.15 >>>>

DISTANCE (M)	CA (KG/M3)	SZ (M)	SY (M)	MIDP (M)	YCU (M)	ZCU (M)	YCL (M)	ZCL (M)	RIB	TMP (DEG.C)	CONC (% VOL.)
0.725E+03	0.972E-04	4.93	75.21	44.66	203.08	13.64	239.91	18.14	28.193	10.0	0.376E-02
0.732E+03	0.961E-04	4.96	75.74	44.65	203.98	13.68	241.10	18.21	28.397	10.0	0.371E-02
0.740E+03	0.950E-04	4.98	76.27	44.63	204.87	13.73	242.29	18.29	28.600	10.0	0.367E-02
0.748E+03	0.939E-04	5.01	76.79	44.61	205.75	13.77	243.47	18.36	28.806	10.0	0.363E-02
0.755E+03	0.929E-04	5.03	77.32	44.60	206.62	13.82	244.64	18.43	29.007	10.0	0.359E-02
0.763E+03	0.918E-04	5.06	77.84	44.58	207.50	13.86	245.81	18.49	29.208	10.0	0.355E-02

HEGADAS Example 2: Input File

```
TITLE HEGADAS-S Chlorine spill
     ICNT   =     0        *                CONTOURS OR CONTENTS CODE
    ISURF   =     3        *                SURFACE TRANSFER CODE
*                          *
POOL   DATA                *
*                          *
   PLL      =  4.00        * M              SOURCE LENGTH
   PLHW     =  2.00        * M              SOURCE HALF-WIDTH
*                          *
AMBIENT CONDITIONS         *
*                          *
   Z0       =  10.0        * M              REFERENCE HEIGHT
   U0       =  2.0         * M/S            WIND VELOCITY AT HEIGHT Z0
   AIRTEMP  =  30.0        * DEG.CELSIUS    AIR TEMP. AT GROUND LEVEL
   RH       =  0.75        *                RELATIVE HUMIDITY
   TGROUND  =  30.0        * DEG.CELSIUS    EARTH-S SURFACE TEMPERATURE
*                          *
DISP                       *
*                          *
   ROUGH    =  0.01        * M              SURFACE ROUGHNESS PARAMETER
   MONIN    =  10000.      * M              MONIN - OBUKHOV LENGTH
   CROSSW   =  0.09158     * M**(1-BETA)    CROSSWIND (DELTA)
               0.905       *                          (BETA)
*                          *
CLOUD                      *
*                          *
   XSTEP    =  1.0         *                OUTPUT STEP LENGTH
   XMAX     =  100.        *                X AT WHICH CALC. IS STOPPED
   CAMIN    =  1.0E-06     * KG/M3          CA AT WHICH CALC. IS STOPPED
   CU       =  1.5E-05     * KG/M3          UPPER CONCENTRATION LIMIT
   CL       =  1.5E-06     * KG/M3          LOWER CONCENTRATION LIMIT
*                          *
SOURCE                     *
*                          *
   FLUX     =  3.0E-02     * KG/M2/S        GAS EMISSION FLUX
   TEMPGAS  = -34.0        * DEG.CELSIUS    TEMPERATURE   OF EMITTED GAS
   CPGAS    =  35.3        * J/MOLE/DEG.C   SPECIFIC HEAT OF EMITTED GAS
   MWGAS    =  70.9        * KG/KMOLE       MOL. WEIGHT OF EMITTED GAS
   WATGAS   =  0.          *                MOLAR FRACTION PICKED-UP WATE
*                          *
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Output File

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                              <<<<  HEGADAS-S Chlorine spill                                  >>>>
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 CALCULATION CODE                 ICNT =      0
 SURFACE HEAT TRANSFER MODEL     ISURF =      3
 THERMODYNAMIC MODEL           THERMOD = NORMAL
 SOURCE LENGTH                     PLL =   4.0000     M
 SOURCE HALF-WIDTH                 PLW =   2.0000     M
 WIND VELOCITY AT HEIGHT Z0         U0 =   2.0000     M/S
 REFERENCE HEIGHT                   Z0 =   10.000     M
 SURFACE ROUGHNESS PARAMETER        ZR =  0.10000E-01 M
 AIR TEMP. AT GROUND LEVEL         TAP =   30.000     DEG.CELSIUS
 MONIN - OBUKHOV LENGTH          OBUKL =   10000.     M
                                 DELTA =  0.91580E-01 M**(1-BETA)
                                  BETA =  0.90500
 SPREADING CONSTANT                 CE =   1.1500
 OUTPUT STEP LENGTH                DX0 =   1.0000
 X AT WHICH CALC. IS STOPPED      XMAX =   100.00
 CA AT WHICH CALC. IS STOPPED    CAMIN =  0.10000E-05 KG/M3
 UPPER CONCENTRATION LIMIT          CU =  0.15000E-04 KG/M3
 LOWER CONCENTRATION LIMIT          CL =  0.15000E-05 KG/M3
 EVAPORATION FLUX                    Q =  0.30000E-01 KG/M2/S =  0.48000      KG/S
 RELATIVE HUMIDITY                   R =  0.75000
 TEMPERATURE   OF EMITTED GAS      TGE =  -34.000     DEG.CELSIUS
 SPECIFIC HEAT OF EMITTED GAS      CPG =   35.300     J/MOLE/DEG.CELSIUS
 MOL. WEIGHT OF EMITTED GAS        FMG =   70.900     KG/KMOLE
 EARTH-S SURFACE TEMPERATURE      TW2P =   30.000     DEG.CELSIUS
 MOLAR FRACTION PICKED-UP WATER    W2P =  0.00000E+00
 HEAT GROUP IN HEAT FLUX QH     HEATGR =   24.000


 WIND PROFILE EXPONENT           ALPHA =  0.18635

                                 USTAR =  0.11857E+00 M/S
1HSMAIN                                  HEGADAS-S PROGRAM ( VERSION AUG88    )                                  PAGE
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                              <<<<  HEGADAS-S Chlorine spill                                  >>>>
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DISTANCE (M)	CA (KG/M3)	SZ (M)	SY (M)	MIDP (M)	YCU (M)	ZCU (M)	YCL (M)	ZCL (M)	RIB	TMP (DEG.C)	CONC (% VOL.)	
-.200E+01	0.345E+01	0.00	0.00	2.00	2.00	0.00	2.00	0.00				
0.200E+01	0.345E+01	0.05	0.00	2.00	2.00	0.45	2.00	0.52	73.211	-31.0	0.965E+02	VISIBLE

TAKE-UP FLUX = 0.0300 KG/M2/S = 0.4802 KG/S

DISTANCE (M)	CA (KG/M3)	SZ (M)	SY (M)	MIDP (M)	YCU (M)	ZCU (M)	YCL (M)	ZCL (M)	RIB	TMP (DEG.C)	CONC (% VOL.)
0.600E+01	0.979E+00	0.07	1.67	3.97	9.52	0.51	10.07	0.60	23.916	20.0	0.332E+02
0.100E+02	0.364E+00	0.11	2.74	5.75	14.46	0.78	15.40	0.92	14.223	27.7	0.127E+02
0.140E+02	0.181E+00	0.16	3.71	7.11	18.47	1.08	19.79	1.30	10.320	29.2	0.633E+01
0.180E+02	0.107E+00	0.22	4.60	8.18	21.89	1.39	23.56	1.69	8.232	29.6	0.375E+01
0.220E+02	0.709E-01	0.28	5.44	9.07	24.89	1.70	26.92	2.09	6.925	29.8	0.248E+01
0.260E+02	0.505E-01	0.34	6.24	9.81	27.59	2.01	29.96	2.48	6.025	29.9	0.177E+01
0.300E+02	0.379E-01	0.41	7.00	10.46	30.06	2.32	32.76	2.88	5.365	29.9	0.133E+01
0.340E+02	0.296E-01	0.47	7.74	11.03	32.34	2.62	35.36	3.27	4.857	29.9	0.104E+01
0.380E+02	0.238E-01	0.54	8.44	11.54	34.47	2.91	37.81	3.66	4.453	29.9	0.836E+00
0.420E+02	0.196E-01	0.61	9.13	12.00	36.47	3.20	40.12	4.05	4.122	30.0	0.689E+00
0.460E+02	0.165E-01	0.68	9.80	12.42	38.36	3.49	42.32	4.43	3.846	30.0	0.578E+00
0.500E+02	0.141E-01	0.74	10.45	12.80	40.15	3.77	44.42	4.81	3.612	30.0	0.493E+00
0.540E+02	0.122E-01	0.81	11.09	13.15	41.86	4.04	46.43	5.18	3.410	30.0	0.427E+00
0.580E+02	0.106E-01	0.88	11.71	13.48	43.49	4.31	48.36	5.55	3.234	30.0	0.373E+00
0.620E+02	0.940E-02	0.95	12.32	13.78	45.05	4.57	50.22	5.92	3.080	30.0	0.329E+00
0.660E+02	0.837E-02	1.02	12.92	14.06	46.56	4.83	52.01	6.28	2.942	30.0	0.293E+00
0.700E+02	0.750E-02	1.09	13.51	14.33	48.01	5.09	53.75	6.63	2.819	30.0	0.263E+00
0.740E+02	0.677E-02	1.16	14.09	14.58	49.40	5.34	55.44	6.99	2.708	30.0	0.238E+00
0.780E+02	0.615E-02	1.23	14.66	14.81	50.76	5.59	57.08	7.34	2.607	30.0	0.216E+00
0.820E+02	0.562E-02	1.30	15.22	15.03	52.07	5.83	58.67	7.69	2.516	30.0	0.197E+00
0.860E+02	0.515E-02	1.37	15.77	15.23	53.34	6.07	60.23	8.03	2.432	30.0	0.181E+00
0.900E+02	0.474E-02	1.44	16.31	15.43	54.57	6.30	61.74	8.37	2.354	30.0	0.166E+00
0.940E+02	0.438E-02	1.51	16.85	15.62	55.77	6.53	63.22	8.71	2.283	30.0	0.154E+00
0.980E+02	0.407E-02	1.58	17.38	15.79	56.93	6.76	64.66	9.04	2.217	30.0	0.143E+00
0.102E+03	0.379E-02	1.65	17.91	15.96	58.07	6.99	66.08	9.37	2.155	30.0	0.133E+00
0.106E+03	0.353E-02	1.72	18.42	16.12	59.18	7.21	67.46	9.70	2.098	30.0	0.124E+00
0.110E+03	0.331E-02	1.79	18.94	16.27	60.26	7.43	68.81	10.02	2.044	30.0	0.116E+00
0.114E+03	0.310E-02	1.86	19.44	16.41	61.31	7.64	70.14	10.34	1.994	30.0	0.109E+00
0.118E+03	0.292E-02	1.94	19.95	16.55	62.35	7.86	71.44	10.66	1.947	30.0	0.102E+00
0.122E+03	0.275E-02	2.01	20.44	16.68	63.35	8.07	72.72	10.98	1.902	30.0	0.965E-01
0.126E+03	0.260E-02	2.08	20.94	16.81	64.34	8.27	73.98	11.29	1.860	30.0	0.912E-01
0.130E+03	0.246E-02	2.15	21.42	16.93	65.31	8.48	75.21	11.61	1.820	30.0	0.863E-01
0.134E+03	0.233E-02	2.22	21.91	17.04	66.25	8.68	76.43	11.91	1.783	30.0	0.818E-01
0.138E+03	0.222E-02	2.29	22.39	17.15	67.18	8.88	77.62	12.22	1.747	30.0	0.777E-01
0.142E+03	0.211E-02	2.36	22.86	17.25	68.09	9.07	78.80	12.52	1.713	30.0	0.739E-01
0.146E+03	0.201E-02	2.43	23.33	17.35	68.98	9.27	79.95	12.83	1.681	30.0	0.704E-01
0.150E+03	0.191E-02	2.50	23.80	17.45	69.86	9.46	81.09	13.12	1.650	30.0	0.671E-01
0.154E+03	0.183E-02	2.57	24.26	17.54	70.71	9.65	82.22	13.42	1.621	30.0	0.641E-01
0.158E+03	0.175E-02	2.64	24.72	17.63	71.56	9.83	83.32	13.72	1.593	30.0	0.613E-01

0.162E+03	0.167E-02	2.71	25.18	17.71	72.39	10.02	84.41	14.01	1.566	30.0	0.587E-01
0.166E+03	0.160E-02	2.78	25.63	17.79	73.20	10.20	85.49	14.30	1.540	30.0	0.563E-01
0.170E+03	0.154E-02	2.85	26.08	17.87	74.00	10.38	86.55	14.59	1.516	30.0	0.540E-01
0.174E+03	0.148E-02	2.92	26.53	17.94	74.79	10.56	87.60	14.87	1.492	30.0	0.518E-01
0.178E+03	0.142E-02	2.99	26.98	18.01	75.56	10.73	88.64	15.16	1.469	30.0	0.498E-01

<<<< HEGADAS-S Chlorine spill >>>>

DISTANCE (M)	CA (KG/M3)	SZ (M)	SY (M)	MIDP (M)	YCU (M)	ZCU (M)	YCL (M)	ZCL (M)	RIB	TMP (DEG.C)	CONC (% VOL.)
0.182E+03	0.137E-02	3.06	27.42	18.08	76.32	10.91	89.66	15.44	1.447	30.0	0.480E-01
0.186E+03	0.132E-02	3.13	27.86	18.15	77.07	11.08	90.67	15.72	1.426	30.0	0.462E-01
0.190E+03	0.127E-02	3.20	28.29	18.21	77.81	11.25	91.66	16.00	1.406	30.0	0.445E-01
0.194E+03	0.123E-02	3.27	28.72	18.27	78.54	11.42	92.65	16.28	1.387	30.0	0.430E-01
0.198E+03	0.118E-02	3.34	29.15	18.32	79.25	11.58	93.62	16.55	1.368	30.0	0.415E-01
0.202E+03	0.114E-02	3.41	29.58	18.38	79.96	11.75	94.58	16.83	1.350	30.0	0.401E-01
0.206E+03	0.111E-02	3.48	30.01	18.43	80.65	11.91	95.54	17.10	1.332	30.0	0.388E-01
0.210E+03	0.107E-02	3.55	30.43	18.48	81.34	12.07	96.48	17.37	1.315	30.0	0.375E-01
0.214E+03	0.104E-02	3.62	30.85	18.53	82.01	12.23	97.41	17.63	1.299	30.0	0.363E-01
0.218E+03	0.100E-02	3.69	31.27	18.57	82.68	12.39	98.33	17.90	1.283	30.0	0.352E-01
0.222E+03	0.973E-03	3.76	31.69	18.62	83.33	12.54	99.24	18.17	1.268	30.0	0.341E-01
0.226E+03	0.944E-03	3.83	32.10	18.66	83.98	12.70	100.14	18.43	1.253	30.0	0.331E-01
0.230E+03	0.916E-03	3.90	32.51	18.70	84.62	12.85	101.04	18.69	1.238	30.0	0.321E-01
0.234E+03	0.889E-03	3.97	32.92	18.73	85.25	13.00	101.92	18.95	1.224	30.0	0.312E-01
0.238E+03	0.864E-03	4.04	33.33	18.77	85.87	13.15	102.80	19.21	1.211	30.0	0.303E-01
0.242E+03	0.840E-03	4.11	33.74	18.80	86.48	13.29	103.66	19.47	1.197	30.0	0.294E-01
0.246E+03	0.817E-03	4.18	34.14	18.83	87.09	13.44	104.52	19.72	1.184	30.0	0.286E-01
0.250E+03	0.795E-03	4.25	34.54	18.87	87.69	13.58	105.37	19.98	1.172	30.0	0.279E-01
0.254E+03	0.774E-03	4.32	34.94	18.89	88.28	13.73	106.22	20.23	1.160	30.0	0.271E-01
0.258E+03	0.753E-03	4.39	35.34	18.92	88.86	13.87	107.05	20.48	1.148	30.0	0.264E-01
0.262E+03	0.734E-03	4.46	35.74	18.95	89.43	14.01	107.88	20.73	1.136	30.0	0.257E-01
0.266E+03	0.715E-03	4.53	36.13	18.97	90.00	14.15	108.70	20.98	1.125	30.0	0.251E-01
0.270E+03	0.698E-03	4.60	36.52	18.99	90.56	14.28	109.51	21.22	1.114	30.0	0.245E-01
0.274E+03	0.680E-03	4.66	36.91	19.02	91.11	14.42	110.32	21.47	1.104	30.0	0.239E-01
0.278E+03	0.664E-03	4.73	37.30	19.04	91.66	14.55	111.12	21.71	1.093	30.0	0.233E-01
0.282E+03	0.648E-03	4.80	37.69	19.05	92.20	14.69	111.91	21.96	1.083	30.0	0.227E-01
0.286E+03	0.633E-03	4.87	38.08	19.07	92.74	14.82	112.69	22.20	1.073	30.0	0.222E-01
0.290E+03	0.618E-03	4.94	38.46	19.09	93.26	14.95	113.47	22.44	1.064	30.0	0.217E-01
0.294E+03	0.604E-03	5.01	38.85	19.10	93.78	15.08	114.25	22.68	1.055	30.0	0.212E-01
0.298E+03	0.591E-03	5.08	39.23	19.12	94.30	15.21	115.01	22.92	1.045	30.0	0.207E-01
0.302E+03	0.578E-03	5.15	39.61	19.13	94.81	15.33	115.77	23.15	1.036	30.0	0.203E-01
0.306E+03	0.565E-03	5.22	39.99	19.14	95.31	15.46	116.53	23.39	1.028	30.0	0.198E-01
0.310E+03	0.553E-03	5.28	40.37	19.15	95.81	15.58	117.28	23.62	1.019	30.0	0.194E-01
0.314E+03	0.541E-03	5.35	40.74	19.16	96.30	15.70	118.02	23.86	1.011	30.0	0.190E-01
0.318E+03	0.530E-03	5.42	41.12	19.17	96.79	15.83	118.76	24.09	1.002	30.0	0.186E-01
0.322E+03	0.519E-03	5.49	41.49	19.18	97.27	15.95	119.49	24.32	0.994	30.0	0.182E-01
0.326E+03	0.508E-03	5.56	41.86	19.18	97.75	16.06	120.21	24.55	0.987	30.0	0.178E-01
0.330E+03	0.498E-03	5.63	42.23	19.19	98.22	16.18	120.94	24.78	0.979	30.0	0.175E-01
0.334E+03	0.488E-03	5.69	42.60	19.19	98.68	16.30	121.65	25.00	0.971	30.0	0.171E-01
0.338E+03	0.478E-03	5.76	42.97	19.20	99.15	16.42	122.36	25.23	0.964	30.0	0.168E-01
0.342E+03	0.469E-03	5.83	43.34	19.20	99.60	16.53	123.07	25.45	0.957	30.0	0.164E-01
0.346E+03	0.460E-03	5.90	43.70	19.20	100.05	16.64	123.77	25.68	0.950	30.0	0.161E-01
0.350E+03	0.451E-03	5.97	44.07	19.20	100.50	16.76	124.46	25.90	0.943	30.0	0.158E-01
0.354E+03	0.443E-03	6.04	44.43	19.20	100.94	16.87	125.15	26.12	0.937	30.0	0.155E-01
0.358E+03	0.434E-03	6.10	44.79	19.20	101.38	16.98	125.84	26.34	0.930	30.0	0.152E-01
0.362E+03	0.426E-03	6.17	45.15	19.20	101.81	17.09	126.52	26.56	0.923	30.0	0.150E-01
0.366E+03	0.419E-03	6.24	45.51	19.19	102.23	17.20	127.20	26.78	0.917	30.0	0.147E-01
0.370E+03	0.411E-03	6.31	45.87	19.19	102.66	17.30	127.87	27.00	0.911	30.0	0.144E-01
0.374E+03	0.404E-03	6.37	46.23	19.19	103.08	17.41	128.54	27.22	0.905	30.0	0.142E-01

<<<< HEGADAS-S Chlorine spill >>>>

DISTANCE (M)	CA (KG/M3)	SZ (M)	SY (M)	MIDP (M)	YCU (M)	ZCU (M)	YCL (M)	ZCL (M)	RIB	TMP (DEG.C)	CONC (% VOL.)
0.378E+03	0.397E-03	6.44	46.58	19.18	103.49	17.51	129.20	27.43	0.899	30.0	0.139E-01
0.382E+03	0.390E-03	6.51	46.94	19.18	103.90	17.62	129.86	27.65	0.893	30.0	0.137E-01
0.386E+03	0.383E-03	6.58	47.29	19.17	104.31	17.72	130.52	27.86	0.887	30.0	0.134E-01
0.390E+03	0.377E-03	6.65	47.65	19.16	104.71	17.82	131.17	28.08	0.881	30.0	0.132E-01
0.394E+03	0.370E-03	6.71	48.00	19.15	105.11	17.93	131.81	28.29	0.876	30.0	0.130E-01
0.398E+03	0.364E-03	6.78	48.35	19.15	105.50	18.03	132.46	28.50	0.871	30.0	0.128E-01

SLAB Example 1: Input File

```
   3
   1
0.070906
498.1
239.1
0.00
287840.
926.3
1574.
-1.0
-1.0
284.3
1.261
.003525
25000.
0.
5.
900.
10000.
0.
1.
2.
4.
.01
10.0
2.0
298.
50.
6.
-1.
```

Output File

```
problem input

  idspl -         3
  ncalc -         1
  wms   -   .070906
  cps   -    498.10
  tbp   -    239.10
  cmed0 -       .00
  dhe   -   287840.
  cpsl  -    926.30
  rhosl -   1574.00
  spb   -     -1.00
  spc   -     -1.00
  ts    -    284.30
  qs    -      1.26
  as    -       .00
  tsd   -    25000.
  qtis  -       .00
  hs    -      5.00
  tav   -    900.00
  xffm  -  10000.00
  zp(1) -       .00
  zp(2) -      1.00
  zp(3) -      2.00
  zp(4) -      4.00
  z0    -   .010000
  za    -     10.00
  ua    -      2.00
  ta    -    298.00
  rh    -     50.00
  stab  -      6.00

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    -  2.8430E+02
 density of source gas (kg/m3)                    - rhos  -  3.0395E+00
 boiling point temperature                        - tbp   -  2.3910E+02
 liquid mass fraction                             - cmed0-   0.0000E+00
 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   -  1.0267E+01
 saturation pressure constant (k)                 - spb   -  2.4548E+03
 saturation pressure constant (k)                 - spc   -  0.0000E+00

spill characteristics

 spill type                                       - idspl-            3
 mass source rate (kg/s)                          - qs    -  1.2610E+00
 continuous source duration (s)                   - tsd   -  2.5000E+04
 continuous source mass (kg)                      - qtcs  -  3.1525E+04
 instantaneous source mass (kg)                   - qtis  -  0.0000E+00
 source area (m2)                                 - as    -  3.5250E-03
 vertical vapor velocity (m/s)                    - ws    -  1.1770E+02
 source half width (m)                            - bs    -  2.9686E-02
 source height (m)                                - hs    -  5.0000E+00
 horizontal vapor velocity (m/s)                  - us    -  0.0000E+00

field parameters

 concentration averaging time (s)                 - tav   -  9.0000E+02
 mixing layer height (m)                          - hmx   -  2.6000E+02
 maximum downwind distrace (m)                    - xffm  -  1.0000E+04
 concentration measurement height (m)             - zp(1)-   0.0000E+00
                                                  - zp(2)-   1.0000E+00
                                                  - zp(3)-   2.0000E+00
                                                  - zp(4)-   4.0000E+00

ambient meteorological properties

 molecular weight of ambient air (kg)             - wmae  -  2.8782E-02
 heat capacity of ambient air at const p. (j/kg-k)- cpaa  -  1.0144E+03
 density of ambient air (kg/m3)                   - rhoa  -  1.1770E+00
 ambient measurement height (m)                   - za    -  1.0000E+01
 ambient atmospheric pressure (pa=n/m2=j/m3)      - pa    -  1.0133E+05
 ambient wind speed (m/s)                         - ua    -  2.0000E+00
 ambient temperature (k)                          - ta    -  2.9800E+02
 relative humidity (percent)                      - rh    -  5.0000E+01
 ambient friction velocity (m/s)                  - uastr -  5.4063E-02
 atmospheric stability class value                - stab  -  6.0000E+00
 inverse monin-obukhov length (1/m)               - ala   -  8.4887E-02
 surface roughness height (m)                     - z0    -  1.0000E-02

additional parameters

 sub-step multiplier                              - ncalc -           1
 number of calculational sub-steps                - nssm  -           3
 acceleration of gravity (m/s2)                   - grav  -  9.8067E+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	i	ia
1.00E+00	5.00E+00	5.94E-02	2.97E-02	2.67E-02	0.00E+00	0.00E+00	1.00E+00	-1.00E+00	-1.00E+00	0.00E+00	2.33E+00
1.95E+00	9.92E+00	5.24E-01	4.19E-01	6.35E-02	9.53E-01	9.53E-01	3.39E-01	-1.00E+00	-1.00E+00	7.30E-01	2.33E+00
2.91E+00	1.18E+01	9.89E-01	8.08E-01	1.00E-01	1.91E+00	1.91E+00	1.14E-01	-1.00E+00	-1.00E+00	1.03E+00	2.33E+00
3.86E+00	1.31E+01	1.45E+00	1.20E+00	1.37E-01	2.86E+00	2.86E+00	5.39E-02	-1.00E+00	-1.00E+00	1.26E+00	2.33E+00
4.81E+00	1.40E+01	1.92E+00	1.59E+00	1.74E-01	3.81E+00	3.81E+00	3.11E-02	-1.00E+00	-1.00E+00	1.46E+00	2.33E+00
5.77E+00	1.48E+01	2.38E+00	1.97E+00	2.10E-01	4.77E+00	4.77E+00	2.01E-02	-1.00E+00	-1.00E+00	1.63E+00	2.33E+00
6.72E+00	1.53E+01	2.85E+00	2.36E+00	2.47E-01	5.72E+00	5.72E+00	1.41E-02	-1.00E+00	-1.00E+00	1.79E+00	2.33E+00
7.67E+00	1.58E+01	3.31E+00	2.75E+00	2.84E-01	6.67E+00	6.67E+00	1.04E-02	-1.00E+00	-1.00E+00	1.93E+00	2.33E+00
8.63E+00	1.61E+01	3.78E+00	3.14E+00	3.21E-01	7.63E+00	7.63E+00	7.95E-03	-1.00E+00	-1.00E+00	2.06E+00	2.33E+00
9.58E+00	1.62E+01	4.24E+00	3.53E+00	3.57E-01	8.58E+00	8.58E+00	6.30E-03	-1.00E+00	-1.00E+00	2.19E+00	2.33E+00
1.05E+01	1.63E+01	4.71E+00	3.92E+00	3.94E-01	9.53E+00	9.53E+00	5.11E-03	1.19E+00	2.98E+02	2.31E+00	2.33E+00
1.07E+01	1.63E+01	4.71E+00	3.93E+00	3.94E-01	9.75E+00	9.75E+00	5.10E-03	1.19E+00	2.98E+02	2.31E+00	2.33E+00
1.10E+01	1.63E+01	4.71E+00	3.94E+00	3.94E-01	1.00E+01	1.00E+01	5.08E-03	1.19E+00	2.98E+02	2.31E+00	2.33E+00
1.13E+01	1.63E+01	4.71E+00	3.95E+00	3.94E-01	1.03E+01	1.03E+01	5.07E-03	1.19E+00	2.98E+02	2.31E+00	2.33E+00
1.17E+01	1.63E+01	4.71E+00	3.96E+00	3.94E-01	1.07E+01	1.07E+01	5.05E-03	1.19E+00	2.98E+02	2.31E+00	2.33E+00
1.21E+01	1.63E+01	4.71E+00	3.97E+00	3.94E-01	1.11E+01	1.11E+01	5.04E-03	1.19E+00	2.98E+02	2.31E+00	2.33E+00
1.26E+01	1.63E+01	4.71E+00	3.99E+00	3.94E-01	1.16E+01	1.16E+01	5.01E-03	1.19E+00	2.98E+02	2.31E+00	2.33E+00
1.33E+01	1.62E+01	4.71E+00	4.01E+00	3.94E-01	1.23E+01	1.23E+01	4.99E-03	1.19E+00	2.98E+02	2.31E+00	2.33E+00
1.40E+01	1.62E+01	4.71E+00	4.04E+00	3.94E-01	1.30E+01	1.30E+01	4.95E-03	1.19E+00	2.98E+02	2.31E+00	2.33E+00
1.50E+01	1.62E+01	4.71E+00	4.07E+00	3.94E-01	1.40E+01	1.40E+01	4.91E-03	1.19E+00	2.98E+02	2.31E+00	2.33E+00
1.61E+01	1.61E+01	4.71E+00	4.11E+00	3.94E-01	1.51E+01	1.51E+01	4.87E-03	1.19E+00	2.98E+02	2.31E+00	2.33E+00
1.74E+01	1.60E+01	4.71E+00	4.15E+00	3.94E-01	1.64E+01	1.64E+01	4.82E-03	1.19E+00	2.98E+02	2.31E+00	2.33E+00
1.90E+01	1.58E+01	4.71E+00	4.20E+00	3.94E-01	1.80E+01	1.80E+01	4.75E-03	1.19E+00	2.98E+02	2.31E+00	2.33E+00
2.09E+01	1.56E+01	4.72E+00	4.27E+00	3.94E-01	1.99E+01	1.99E+01	4.68E-03	1.19E+00	2.98E+02	2.31E+00	2.33E+00
2.32E+01	1.52E+01	4.72E+00	4.35E+00	3.94E-01	2.22E+01	2.22E+01	4.60E-03	1.19E+00	2.98E+02	2.31E+00	2.33E+00
2.59E+01	1.47E+01	4.72E+00	4.44E+00	3.94E-01	2.49E+01	2.49E+01	4.50E-03	1.19E+00	2.98E+02	2.31E+00	2.33E+00
2.92E+01	1.41E+01	4.73E+00	4.55E+00	3.94E-01	2.82E+01	2.82E+01	4.39E-03	1.18E+00	2.98E+02	2.31E+00	2.33E+00
3.32E+01	1.31E+01	4.78E+00	4.68E+00	3.94E-01	3.22E+01	3.22E+01	4.26E-03	1.18E+00	2.98E+02	2.28E+00	2.30E+00
3.79E+01	1.17E+01	4.92E+00	4.84E+00	3.94E-01	3.69E+01	3.69E+01	4.11E-03	1.18E+00	2.98E+02	2.22E+00	2.23E+00
4.37E+01	9.62E+00	5.15E+00	5.03E+00	3.94E-01	4.27E+01	4.27E+01	3.95E-03	1.18E+00	2.98E+02	2.12E+00	2.13E+00
5.05E+01	6.56E+00	5.62E+00	5.26E+00	3.94E-01	4.95E+01	4.95E+01	3.77E-03	1.18E+00	2.98E+02	1.95E+00	1.96E+00
5.88E+01	1.95E+00	5.38E+00	7.13E+00	5.09E-01	5.78E+01	5.78E+01	3.54E-03	1.18E+00	2.98E+02	1.60E+00	1.61E+00
6.87E+01	7.04E-01	2.79E+00	2.04E+01	1.42E+00	6.77E+01	6.77E+01	3.03E-03	1.18E+00	2.98E+02	1.26E+00	1.25E+00
8.06E+01	4.15E-01	2.30E+00	3.51E+01	2.41E+00	7.96E+01	7.96E+01	2.31E-03	1.18E+00	2.98E+02	1.16E+00	1.16E+00
9.49E+01	3.02E-01	2.22E+00	4.88E+01	3.32E+00	9.39E+01	9.39E+01	1.75E-03	1.18E+00	2.98E+02	1.15E+00	1.14E+00
1.12E+02	2.42E-01	2.26E+00	6.14E+01	4.15E+00	1.11E+02	1.11E+02	1.37E-03	1.18E+00	2.98E+02	1.15E+00	1.14E+00
1.33E+02	2.04E-01	2.37E+00	7.33E+01	4.91E+00	1.32E+02	1.32E+02	1.09E-03	1.18E+00	2.98E+02	1.15E+00	1.14E+00
1.57E+02	1.78E-01	2.52E+00	8.47E+01	5.64E+00	1.56E+02	1.56E+02	8.88E-04	1.18E+00	2.98E+02	1.15E+00	1.15E+00
1.87E+02	1.58E-01	2.71E+00	9.59E+01	6.33E+00	1.86E+02	1.86E+02	7.27E-04	1.18E+00	2.98E+02	1.15E+00	1.15E+00
2.23E+02	1.43E-01	2.93E+00	1.07E+02	7.01E+00	2.22E+02	2.22E+02	5.98E-04	1.18E+00	2.98E+02	1.16E+00	1.16E+00
2.66E+02	1.31E-01	3.20E+00	1.18E+02	7.67E+00	2.65E+02	2.65E+02	4.93E-04	1.18E+00	2.98E+02	1.17E+00	1.17E+00
3.17E+02	1.21E-01	3.50E+00	1.29E+02	8.32E+00	3.16E+02	3.16E+02	4.07E-04	1.18E+00	2.98E+02	1.18E+00	1.18E+00
3.79E+02	1.12E-01	3.85E+00	1.40E+02	8.96E+00	3.78E+02	3.78E+02	3.36E-04	1.18E+00	2.98E+02	1.20E+00	1.20E+00
4.54E+02	1.05E-01	4.24E+00	1.51E+02	9.58E+00	4.53E+02	4.52E+02	2.77E-04	1.18E+00	2.98E+02	1.22E+00	1.23E+00
5.43E+02	9.83E-02	4.68E+00	1.63E+02	1.02E+01	5.42E+02	5.42E+02	2.29E-04	1.18E+00	2.98E+02	1.25E+00	1.25E+00
6.50E+02	9.28E-02	5.17E+00	1.74E+02	1.08E+01	6.49E+02	6.49E+02	1.89E-04	1.18E+00	2.98E+02	1.28E+00	1.28E+00
7.79E+02	8.78E-02	5.72E+00	1.87E+02	1.14E+01	7.78E+02	7.78E+02	1.55E-04	1.18E+00	2.98E+02	1.31E+00	1.31E+00
9.33E+02	8.33E-02	6.34E+00	1.99E+02	1.20E+01	9.32E+02	9.32E+02	1.28E-04	1.18E+00	2.98E+02	1.35E+00	1.35E+00
1.12E+03	7.93E-02	7.02E+00	2.12E+02	1.27E+01	1.12E+03	1.12E+03	1.05E-04	1.18E+00	2.98E+02	1.38E+00	1.39E+00
1.34E+03	7.55E-02	7.78E+00	2.26E+02	1.33E+01	1.34E+03	1.34E+03	8.67E-05	1.18E+00	2.98E+02	1.43E+00	1.43E+00
1.61E+03	7.20E-02	8.62E+00	2.41E+02	1.39E+01	1.61E+03	1.61E+03	7.12E-05	1.18E+00	2.98E+02	1.47E+00	1.47E+00
1.93E+03	6.88E-02	9.55E+00	2.57E+02	1.46E+01	1.93E+03	1.93E+03	5.85E-05	1.18E+00	2.98E+02	1.51E+00	1.52E+00
2.32E+03	6.57E-02	1.06E+01	2.75E+02	1.53E+01	2.32E+03	2.32E+03	4.79E-05	1.18E+00	2.98E+02	1.56E+00	1.56E+00
2.78E+03	6.27E-02	1.17E+01	2.94E+02	1.60E+01	2.78E+03	2.78E+03	3.92E-05	1.18E+00	2.98E+02	1.61E+00	1.61E+00
3.34E+03	5.99E-02	1.30E+01	3.15E+02	1.67E+01	3.34E+03	3.34E+03	3.20E-05	1.18E+00	2.98E+02	1.66E+00	1.66E+00
4.01E+03	5.72E-02	1.44E+01	3.38E+02	1.75E+01	4.01E+03	4.01E+03	2.61E-05	1.18E+00	2.98E+02	1.72E+00	1.72E+00
4.81E+03	5.46E-02	1.59E+01	3.63E+02	1.84E+01	4.81E+03	4.81E+03	2.12E-05	1.18E+00	2.98E+02	1.77E+00	1.77E+00
5.78E+03	5.21E-02	1.76E+01	3.91E+02	1.93E+01	5.78E+03	5.78E+03	1.72E-05	1.18E+00	2.98E+02	1.83E+00	1.83E+00
6.94E+03	4.96E-02	1.96E+01	4.22E+02	2.02E+01	6.93E+03	6.93E+03	1.40E-05	1.18E+00	2.98E+02	1.89E+00	1.89E+00
8.33E+03	4.73E-02	2.17E+01	4.57E+02	2.12E+01	8.33E+03	8.33E+03	1.13E-05	1.18E+00	2.98E+02	1.95E+00	1.95E+00
1.00E+04	4.50E-02	2.40E+01	4.96E+02	2.23E+01	1.00E+04	1.00E+04	9.09E-06	1.18E+00	2.98E+02	2.01E+00	2.01E+00

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x	cm	cmv	cmda	cmw	cmwv	wc	vg	ug	w	v	vx
1.00E+00	1.00E+00	-1.00E+00	0.00E+00	0.00E+00	-1.00E+00	1.18E+02	0.00E+00	0.00E+00	-1.00E+00	-1.00E+00	0.00E+00
1.95E+00	5.58E-01	-1.00E+00	4.37E-01	4.51E-03	-1.00E+00	8.05E+01	0.00E+00	0.00E+00	-1.00E+00	-1.00E+00	0.00E+00
2.91E+00	2.40E-01	-1.00E+00	7.52E-01	7.76E-03	-1.00E+00	6.51E+01	0.00E+00	0.00E+00	-1.00E+00	-1.00E+00	0.00E+00
3.86E+00	1.23E-01	-1.00E+00	8.68E-01	8.95E-03	-1.00E+00	5.32E+01	0.00E+00	0.00E+00	-1.00E+00	-1.00E+00	0.00E+00
4.81E+00	7.32E-02	-1.00E+00	9.17E-01	9.46E-03	-1.00E+00	4.33E+01	0.00E+00	0.00E+00	-1.00E+00	-1.00E+00	0.00E+00
5.77E+00	4.81E-02	-1.00E+00	9.42E-01	9.71E-03	-1.00E+00	3.45E+01	0.00E+00	0.00E+00	-1.00E+00	-1.00E+00	0.00E+00
6.72E+00	3.39E-02	-1.00E+00	9.56E-01	9.86E-03	-1.00E+00	2.65E+01	0.00E+00	0.00E+00	-1.00E+00	-1.00E+00	0.00E+00
7.67E+00	2.52E-02	-1.00E+00	9.65E-01	9.95E-03	-1.00E+00	1.92E+01	0.00E+00	0.00E+00	-1.00E+00	-1.00E+00	0.00E+00
8.63E+00	1.94E-02	-1.00E+00	9.71E-01	1.00E-02	-1.00E+00	1.24E+01	0.00E+00	0.00E+00	-1.00E+00	-1.00E+00	0.00E+00
9.58E+00	1.54E-02	-1.00E+00	9.75E-01	1.00E-02	-1.00E+00	6.04E+00	0.00E+00	0.00E+00	-1.00E+00	-1.00E+00	0.00E+00
1.05E+01	1.25E-02	1.25E-02	9.77E-01	1.01E-02	1.01E-02	0.00E+00	0.00E+00	0.00E+00	1.97E-02	4.52E-02	0.00E+00
1.07E+01	1.25E-02	1.25E-02	9.77E-01	1.01E-02	1.01E-02	-6.91E-03	0.00E+00	0.00E+00	6.63E-04	4.52E-02	4.19E-01
1.10E+01	1.24E-02	1.24E-02	9.77E-01	1.01E-02	1.01E-02	-1.52E-02	0.00E+00	0.00E+00	6.65E-04	4.52E-02	4.19E-01
1.13E+01	1.24E-02	1.24E-02	9.78E-01	1.01E-02	1.01E-02	-2.51E-02	0.00E+00	0.00E+00	6.66E-04	4.52E-02	4.19E-01
1.17E+01	1.24E-02	1.24E-02	9.78E-01	1.01E-02	1.01E-02	-3.69E-02	0.00E+00	0.00E+00	6.69E-04	4.52E-02	4.19E-01
1.21E+01	1.23E-02	1.23E-02	9.78E-01	1.01E-02	1.01E-02	-5.09E-02	0.00E+00	0.00E+00	6.71E-04	4.52E-02	4.19E-01
1.26E+01	1.23E-02	1.23E-02	9.78E-01	1.01E-02	1.01E-02	-6.77E-02	0.00E+00	0.00E+00	6.75E-04	4.52E-02	4.19E-01
1.33E+01	1.22E-02	1.22E-02	9.78E-01	1.01E-02	1.01E-02	-8.76E-02	0.00E+00	0.00E+00	6.79E-04	4.52E-02	4.19E-01
1.40E+01	1.21E-02	1.21E-02	9.78E-01	1.01E-02	1.01E-02	-1.11E-01	0.00E+00	0.00E+00	6.85E-04	4.52E-02	4.19E-01
1.50E+01	1.20E-02	1.20E-02	9.78E-01	1.01E-02	1.01E-02	-1.39E-01	0.00E+00	0.00E+00	6.92E-04	4.51E-02	4.19E-01
1.61E+01	1.19E-02	1.19E-02	9.78E-01	1.01E-02	1.01E-02	-1.72E-01	0.00E+00	0.00E+00	7.02E-04	4.51E-02	4.19E-01
1.74E+01	1.18E-02	1.18E-02	9.78E-01	1.01E-02	1.01E-02	-2.11E-01	0.00E+00	0.00E+00	7.15E-04	4.51E-02	4.19E-01
1.90E+01	1.16E-02	1.16E-02	9.78E-01	1.01E-02	1.01E-02	-2.57E-01	0.00E+00	0.00E+00	7.33E-04	4.51E-02	4.19E-01
2.09E+01	1.15E-02	1.15E-02	9.78E-01	1.01E-02	1.01E-02	-3.10E-01	0.00E+00	0.00E+00	7.57E-04	4.50E-02	4.18E-01
2.32E+01	1.12E-02	1.12E-02	9.79E-01	1.01E-02	1.01E-02	-3.71E-01	0.00E+00	0.00E+00	7.91E-04	4.50E-02	4.18E-01
2.59E+01	1.10E-02	1.10E-02	9.79E-01	1.01E-02	1.01E-02	-4.42E-01	0.00E+00	0.00E+00	8.40E-04	4.49E-02	4.17E-01
2.92E+01	1.07E-02	1.07E-02	9.79E-01	1.01E-02	1.01E-02	-5.22E-01	0.00E+00	0.00E+00	9.12E-04	4.49E-02	4.16E-01
3.32E+01	1.04E-02	1.04E-02	9.79E-01	1.01E-02	1.01E-02	-6.13E-01	0.00E+00	0.00E+00	1.03E-03	4.43E-02	4.14E-01
3.79E+01	1.01E-02	1.01E-02	9.80E-01	1.01E-02	1.01E-02	-7.17E-01	0.00E+00	0.00E+00	1.22E-03	4.30E-02	4.10E-01
4.37E+01	9.68E-03	9.68E-03	9.80E-01	1.01E-02	1.01E-02	-8.37E-01	0.00E+00	0.00E+00	1.63E-03	4.10E-02	4.03E-01

5.05E+01	9.24E-03	9.24E-03	9.81E-01	1.01E-02	1.01E-02	-9.75E-01	0.00E+00	0.00E+00	2.93E-03	3.76E-02	3.82E-01
5.88E+01	8.67E-03	8.67E-03	9.81E-01	1.01E-02	1.01E-02	-5.13E-01	1.88E+00	0.00E+00	2.54E-02	3.06E-02	3.01E-01
6.87E+01	7.43E-03	7.43E-03	9.82E-01	1.01E-02	1.01E-02	-5.70E-02	1.65E+00	0.00E+00	4.03E-02	2.21E-02	2.19E-01
8.06E+01	5.67E-03	5.67E-03	9.84E-01	1.01E-02	1.01E-02	-1.47E-02	1.25E+00	0.00E+00	3.29E-02	1.90E-02	1.92E-01
9.49E+01	4.30E-03	4.30E-03	9.86E-01	1.02E-02	1.02E-02	-5.73E-03	9.28E-01	0.00E+00	2.38E-02	1.76E-02	1.82E-01
1.12E+02	3.36E-03	3.36E-03	9.86E-01	1.02E-02	1.02E-02	-2.81E-03	7.12E-01	0.00E+00	1.80E-02	1.66E-02	1.80E-01
1.33E+02	2.69E-03	2.69E-03	9.87E-01	1.02E-02	1.02E-02	-1.57E-03	5.62E-01	0.00E+00	1.44E-02	1.59E-02	1.80E-01
1.57E+02	2.18E-03	2.18E-03	9.88E-01	1.02E-02	1.02E-02	-9.49E-04	4.52E-01	0.00E+00	1.21E-02	1.52E-02	1.82E-01
1.87E+02	1.79E-03	1.79E-03	9.88E-01	1.02E-02	1.02E-02	-6.07E-04	3.68E-01	0.00E+00	1.05E-02	1.46E-02	1.86E-01
2.23E+02	1.47E-03	1.47E-03	9.88E-01	1.02E-02	1.02E-02	-4.04E-04	3.02E-01	0.00E+00	9.34E-03	1.41E-02	1.91E-01
2.66E+02	1.21E-03	1.21E-03	9.89E-01	1.02E-02	1.02E-02	-2.77E-04	2.50E-01	0.00E+00	8.47E-03	1.37E-02	1.97E-01
3.17E+02	1.00E-03	1.00E-03	9.89E-01	1.02E-02	1.02E-02	-1.95E-04	2.09E-01	0.00E+00	7.77E-03	1.34E-02	2.03E-01
3.79E+02	8.27E-04	8.27E-04	9.89E-01	1.02E-02	1.02E-02	-1.40E-04	1.75E-01	0.00E+00	7.20E-03	1.31E-02	2.11E-01
4.54E+02	6.83E-04	6.83E-04	9.89E-01	1.02E-02	1.02E-02	-1.02E-04	1.48E-01	0.00E+00	6.71E-03	1.29E-02	2.19E-01
5.43E+02	5.63E-04	5.63E-04	9.89E-01	1.02E-02	1.02E-02	-7.58E-05	1.25E-01	0.00E+00	6.29E-03	1.27E-02	2.27E-01
6.50E+02	4.64E-04	4.64E-04	9.89E-01	1.02E-02	1.02E-02	-5.71E-05	1.07E-01	0.00E+00	5.91E-03	1.26E-02	2.36E-01
7.79E+02	3.83E-04	3.83E-04	9.89E-01	1.02E-02	1.02E-02	-4.37E-05	9.27E-02	0.00E+00	5.57E-03	1.24E-02	2.46E-01
9.33E+02	3.15E-04	3.15E-04	9.89E-01	1.02E-02	1.02E-02	-3.38E-05	8.08E-02	0.00E+00	5.26E-03	1.23E-02	2.55E-01
1.12E+03	2.60E-04	2.60E-04	9.90E-01	1.02E-02	1.02E-02	-2.65E-05	7.11E-02	0.00E+00	4.98E-03	1.23E-02	2.65E-01
1.34E+03	2.14E-04	2.14E-04	9.90E-01	1.02E-02	1.02E-02	-2.11E-05	6.31E-02	0.00E+00	4.72E-03	1.22E-02	2.75E-01
1.61E+03	1.75E-04	1.75E-04	9.90E-01	1.02E-02	1.02E-02	-1.69E-05	5.65E-02	0.00E+00	4.48E-03	1.21E-02	2.86E-01
1.93E+03	1.44E-04	1.44E-04	9.90E-01	1.02E-02	1.02E-02	-1.37E-05	5.11E-02	0.00E+00	4.25E-03	1.20E-02	2.96E-01
2.32E+03	1.18E-04	1.18E-04	9.90E-01	1.02E-02	1.02E-02	-1.11E-05	4.66E-02	0.00E+00	4.05E-03	1.19E-02	3.06E-01
2.78E+03	9.66E-05	9.66E-05	9.90E-01	1.02E-02	1.02E-02	-9.14E-06	4.28E-02	0.00E+00	3.86E-03	1.18E-02	3.16E-01
3.34E+03	7.89E-05	7.89E-05	9.90E-01	1.02E-02	1.02E-02	-7.54E-06	3.96E-02	0.00E+00	3.68E-03	1.16E-02	3.26E-01
4.01E+03	6.43E-05	6.43E-05	9.90E-01	1.02E-02	1.02E-02	-6.23E-06	3.68E-02	0.00E+00	3.51E-03	1.15E-02	3.36E-01
4.81E+03	5.23E-05	5.23E-05	9.90E-01	1.02E-02	1.02E-02	-5.16E-06	3.43E-02	0.00E+00	3.35E-03	1.13E-02	3.45E-01
5.78E+03	4.25E-05	4.25E-05	9.90E-01	1.02E-02	1.02E-02	-4.28E-06	3.22E-02	0.00E+00	3.20E-03	1.10E-02	3.54E-01
6.94E+03	3.44E-05	3.44E-05	9.90E-01	1.02E-02	1.02E-02	-3.55E-06	3.02E-02	0.00E+00	3.06E-03	1.08E-02	3.63E-01
8.33E+03	2.78E-05	2.78E-05	9.90E-01	1.02E-02	1.02E-02	-2.94E-06	2.84E-02	0.00E+00	2.93E-03	1.05E-02	3.71E-01
1.00E+04	2.24E-05	2.24E-05	9.90E-01	1.02E-02	1.02E-02	-2.43E-06	2.68E-02	0.00E+00	2.80E-03	1.02E-02	3.78E-01

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time averaged (tav = 900. 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)
1.00E+00	0.00E+00	2.67E-02	7.47E-03	5.00E+00	1.71E-02	0.00E+00	1.00E+00	0.00E+00	0.00E+00
1.95E+00	7.85E-01	6.35E-02	2.43E-01	9.92E+00	1.51E-01	8.26E-01	1.95E+00	9.53E-01	7.79E-03
2.91E+00	3.22E-01	1.00E-01	4.70E-01	1.18E+01	2.85E-01	1.65E+00	2.91E+00	1.91E+00	1.56E-02
3.86E+00	1.66E-01	1.37E-01	6.98E-01	1.31E+01	4.20E-01	2.48E+00	3.86E+00	2.86E+00	2.34E-02
4.81E+00	9.97E-02	1.74E-01	9.26E-01	1.40E+01	5.54E-01	3.30E+00	4.81E+00	3.81E+00	3.11E-02
5.77E+00	6.63E-02	2.10E-01	1.15E+00	1.48E+01	6.88E-01	4.13E+00	5.77E+00	4.77E+00	3.89E-02
6.72E+00	4.72E-02	2.47E-01	1.38E+00	1.53E+01	8.22E-01	4.96E+00	6.72E+00	5.72E+00	4.67E-02
7.67E+00	3.53E-02	2.84E-01	1.61E+00	1.58E+01	9.56E-01	5.78E+00	7.67E+00	6.67E+00	5.45E-02
8.63E+00	2.74E-02	3.21E-01	1.84E+00	1.61E+01	1.09E+00	6.61E+00	8.63E+00	7.63E+00	6.23E-02
9.58E+00	2.19E-02	3.57E-01	2.06E+00	1.62E+01	1.22E+00	7.44E+00	9.58E+00	8.58E+00	7.01E-02
1.05E+01	1.78E-02	3.94E-01	2.29E+00	1.63E+01	1.36E+00	8.26E+00	1.05E+01	9.53E+00	7.79E-02
1.07E+01	1.79E-02	3.94E-01	2.30E+00	1.63E+01	1.36E+00	8.45E+00	1.07E+01	9.75E+00	7.96E-02
1.10E+01	1.79E-02	3.94E-01	2.30E+00	1.63E+01	1.36E+00	8.67E+00	1.10E+01	1.00E+01	8.17E-02
1.13E+01	1.79E-02	3.94E-01	2.31E+00	1.63E+01	1.36E+00	8.93E+00	1.13E+01	1.03E+01	8.42E-02
1.17E+01	1.79E-02	3.94E-01	2.32E+00	1.63E+01	1.36E+00	9.25E+00	1.17E+01	1.07E+01	8.71E-02
1.21E+01	1.79E-02	3.94E-01	2.34E+00	1.63E+01	1.36E+00	9.63E+00	1.21E+01	1.11E+01	9.08E-02
1.26E+01	1.80E-02	3.94E-01	2.35E+00	1.63E+01	1.36E+00	1.01E+01	1.26E+01	1.16E+01	9.51E-02
1.33E+01	1.80E-02	3.94E-01	2.37E+00	1.62E+01	1.36E+00	1.06E+01	1.33E+01	1.23E+01	1.00E-01
1.40E+01	1.81E-02	3.94E-01	2.39E+00	1.62E+01	1.36E+00	1.13E+01	1.40E+01	1.30E+01	1.06E-01
1.50E+01	1.81E-02	3.94E-01	2.42E+00	1.62E+01	1.36E+00	1.21E+01	1.50E+01	1.40E+01	1.14E-01
1.61E+01	1.82E-02	3.94E-01	2.45E+00	1.61E+01	1.36E+00	1.30E+01	1.61E+01	1.51E+01	1.23E-01
1.74E+01	1.83E-02	3.94E-01	2.49E+00	1.60E+01	1.36E+00	1.42E+01	1.74E+01	1.64E+01	1.34E-01
1.90E+01	1.84E-02	3.94E-01	2.54E+00	1.58E+01	1.36E+00	1.56E+01	1.90E+01	1.80E+01	1.47E-01
2.09E+01	1.86E-02	3.94E-01	2.61E+00	1.56E+01	1.36E+00	1.72E+01	2.09E+01	1.99E+01	1.62E-01
2.32E+01	1.88E-02	3.94E-01	2.69E+00	1.52E+01	1.36E+00	1.92E+01	2.32E+01	2.22E+01	1.81E-01
2.59E+01	1.91E-02	3.94E-01	2.78E+00	1.47E+01	1.36E+00	2.16E+01	2.59E+01	2.49E+01	2.03E-01
2.92E+01	1.94E-02	3.94E-01	2.90E+00	1.41E+01	1.36E+00	2.45E+01	2.92E+01	2.82E+01	2.30E-01
3.32E+01	1.98E-02	3.94E-01	3.05E+00	1.31E+01	1.38E+00	2.79E+01	3.32E+01	3.22E+01	2.63E-01
3.79E+01	2.02E-02	3.94E-01	3.23E+00	1.17E+01	1.42E+00	3.21E+01	3.79E+01	3.69E+01	3.02E-01
4.37E+01	2.08E-02	3.94E-01	3.46E+00	9.62E+00	1.49E+00	3.74E+01	4.37E+01	4.27E+01	3.48E-01
5.05E+01	2.14E-02	3.94E-01	3.74E+00	6.56E+00	1.62E+00	4.41E+01	5.05E+01	4.95E+01	4.05E-01
5.88E+01	1.58E-02	5.09E-01	4.84E+00	1.95E+00	1.98E+00	5.34E+01	5.88E+01	5.78E+01	4.72E-01
6.87E+01	1.04E-02	1.42E+00	1.21E+01	7.04E-01	1.21E+00	6.77E+01	6.87E+01	6.77E+01	5.53E-01
8.06E+01	7.19E-03	2.41E+00	2.05E+01	4.15E-01	1.09E+00	8.76E+01	8.06E+01	7.96E+01	6.50E-01
9.49E+01	5.20E-03	3.32E+00	2.84E+01	3.02E-01	1.11E+00	1.12E+02	9.49E+01	9.39E+01	7.67E-01
1.12E+02	3.95E-03	4.15E+00	3.57E+01	2.42E-01	1.17E+00	1.42E+02	1.12E+02	1.11E+02	9.07E-01
1.33E+02	3.11E-03	4.91E+00	4.26E+01	2.04E-01	1.25E+00	1.78E+02	1.33E+02	1.32E+02	1.08E+00
1.57E+02	2.50E-03	5.64E+00	4.93E+01	1.78E-01	1.35E+00	2.22E+02	1.57E+02	1.56E+02	1.28E+00
1.87E+02	2.04E-03	6.33E+00	5.59E+01	1.58E-01	1.47E+00	2.73E+02	1.87E+02	1.86E+02	1.52E+00
2.23E+02	1.68E-03	7.01E+00	6.24E+01	1.43E-01	1.61E+00	3.35E+02	2.23E+02	2.22E+02	1.81E+00
2.66E+02	1.39E-03	7.67E+00	6.90E+01	1.31E-01	1.77E+00	4.09E+02	2.66E+02	2.65E+02	2.16E+00
3.17E+02	1.15E-03	8.32E+00	7.56E+01	1.21E-01	1.95E+00	4.97E+02	3.17E+02	3.16E+02	2.58E+00
3.79E+02	9.54E-04	8.96E+00	8.24E+01	1.12E-01	2.16E+00	6.01E+02	3.79E+02	3.78E+02	3.09E+00
4.54E+02	7.94E-04	9.58E+00	8.93E+01	1.05E-01	2.39E+00	7.23E+02	4.54E+02	4.52E+02	3.69E+00
5.43E+02	6.63E-04	1.02E+01	9.66E+01	9.83E-02	2.64E+00	8.68E+02	5.43E+02	5.42E+02	4.42E+00
6.50E+02	5.54E-04	1.08E+01	1.04E+02	9.28E-02	2.93E+00	1.04E+03	6.50E+02	6.49E+02	5.30E+00

7.79E+02	4.65E-04	1.14E+01	1.12E+02	8.78E-02	3.25E+00	1.24E+03	7.79E+02	7.78E+02	6.35E+00
9.33E+02	3.91E-04	1.20E+01	1.21E+02	8.33E-02	3.61E+00	1.47E+03	9.33E+02	9.32E+02	7.61E+00
1.12E+03	3.29E-04	1.27E+01	1.30E+02	7.93E-02	4.01E+00	1.74E+03	1.12E+03	1.12E+03	9.13E+00
1.34E+03	2.78E-04	1.33E+01	1.41E+02	7.55E-02	4.45E+00	2.06E+03	1.34E+03	1.34E+03	1.10E+01
1.61E+03	2.36E-04	1.39E+01	1.52E+02	7.20E-02	4.93E+00	2.43E+03	1.61E+03	1.61E+03	1.31E+01
1.93E+03	2.00E-04	1.46E+01	1.66E+02	6.88E-02	5.47E+00	2.86E+03	1.93E+03	1.93E+03	1.58E+01
2.32E+03	1.71E-04	1.53E+01	1.80E+02	6.57E-02	6.07E+00	3.36E+03	2.32E+03	2.32E+03	1.89E+01
2.78E+03	1.46E-04	1.60E+01	1.97E+02	6.27E-02	6.73E+00	3.95E+03	2.78E+03	2.78E+03	2.27E+01
3.34E+03	1.24E-04	1.67E+01	2.16E+02	5.99E-02	7.46E+00	4.63E+03	3.34E+03	3.34E+03	2.73E+01
4.01E+03	1.06E-04	1.75E+01	2.38E+02	5.72E-02	8.27E+00	5.42E+03	4.01E+03	4.01E+03	3.27E+01
4.81E+03	9.11E-05	1.84E+01	2.62E+02	5.46E-02	9.16E+00	6.34E+03	4.81E+03	4.81E+03	3.93E+01
5.78E+03	7.79E-05	1.93E+01	2.90E+02	5.21E-02	1.02E+01	7.41E+03	5.78E+03	5.78E+03	4.72E+01
6.94E+03	6.66E-05	2.02E+01	3.21E+02	4.96E-02	1.13E+01	8.66E+03	6.94E+03	6.93E+03	5.66E+01
8.33E+03	5.69E-05	2.12E+01	3.57E+02	4.73E-02	1.25E+01	1.01E+04	8.33E+03	8.33E+03	6.80E+01
1.00E+04	4.86E-05	2.23E+01	3.97E+02	4.50E-02	1.39E+01	1.18E+04	1.00E+04	1.00E+04	8.16E+01

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time averaged (tav = 900. s) volume concentration: concentration in the z = .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	1.25E+04	2.50E+04	2.97E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1.95E+00	1.25E+04	2.50E+04	4.25E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2.91E+00	1.25E+04	2.50E+04	8.21E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3.86E+00	1.25E+04	2.50E+04	1.22E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4.81E+00	1.25E+04	2.50E+04	1.61E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
5.77E+00	1.25E+04	2.50E+04	2.01E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
6.72E+00	1.25E+04	2.50E+04	2.40E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
7.67E+00	1.25E+04	2.50E+04	2.80E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
8.63E+00	1.25E+04	2.50E+04	3.20E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
9.58E+00	1.25E+04	2.50E+04	3.59E+00	1.69E-40	1.16E-40	3.78E-41	5.79E-42	4.19E-43	1.40E-44
1.05E+01	1.25E+04	2.50E+04	3.99E+00	1.21E-33	8.30E-34	2.69E-34	4.13E-35	2.99E-36	1.02E-37
1.07E+01	1.25E+04	2.50E+04	4.00E+00	1.22E-33	8.37E-34	2.72E-34	4.17E-35	3.02E-36	1.03E-37
1.10E+01	1.25E+04	2.50E+04	4.01E+00	1.23E-33	8.46E-34	2.75E-34	4.21E-35	3.05E-36	1.04E-37
1.13E+01	1.25E+04	2.50E+04	4.02E+00	1.26E-33	8.67E-34	2.82E-34	4.32E-35	3.13E-36	1.07E-37
1.17E+01	1.25E+04	2.50E+04	4.04E+00	1.32E-33	9.07E-34	2.94E-34	4.51E-35	3.27E-36	1.12E-37
1.21E+01	1.25E+04	2.50E+04	4.06E+00	1.42E-33	9.79E-34	3.18E-34	4.87E-35	3.53E-36	1.21E-37
1.26E+01	1.25E+04	2.50E+04	4.09E+00	1.61E-33	1.11E-33	3.59E-34	5.51E-35	3.99E-36	1.36E-37
1.33E+01	1.25E+04	2.50E+04	4.12E+00	1.95E-33	1.34E-33	4.36E-34	6.68E-35	4.84E-36	1.66E-37
1.40E+01	1.25E+04	2.50E+04	4.16E+00	2.62E-33	1.80E-33	5.86E-34	8.98E-35	6.50E-36	2.23E-37
1.50E+01	1.25E+04	2.50E+04	4.21E+00	4.10E-33	2.82E-33	9.15E-34	1.40E-34	1.02E-35	3.47E-37
1.61E+01	1.25E+04	2.50E+04	4.27E+00	7.95E-33	5.46E-33	1.77E-33	2.72E-34	1.97E-35	6.74E-37
1.74E+01	1.25E+04	2.50E+04	4.34E+00	2.10E-32	1.45E-32	4.69E-33	7.19E-34	5.21E-35	1.78E-36
1.90E+01	1.25E+04	2.50E+04	4.43E+00	8.61E-32	5.92E-32	1.92E-32	2.95E-33	2.13E-34	7.30E-36
2.09E+01	1.25E+04	2.50E+04	4.53E+00	6.50E-31	4.46E-31	1.45E-31	2.22E-32	1.61E-33	5.51E-35
2.32E+01	1.25E+04	2.50E+04	4.67E+00	1.13E-29	7.75E-30	2.52E-30	3.86E-31	2.79E-32	9.56E-34
2.59E+01	1.25E+04	2.50E+04	4.83E+00	5.95E-28	4.09E-28	1.33E-28	2.03E-29	1.47E-30	5.03E-32
2.92E+01	1.25E+04	2.50E+04	5.04E+00	1.30E-25	8.96E-26	2.91E-26	4.46E-27	3.23E-28	1.10E-29
3.32E+01	1.25E+04	2.50E+04	5.29E+00	4.96E-22	3.41E-22	1.11E-22	1.70E-23	1.23E-24	4.21E-26
3.79E+01	1.25E+04	2.50E+04	5.61E+00	2.96E-17	2.04E-17	6.61E-18	1.01E-18	7.34E-20	2.51E-21
4.37E+01	1.25E+04	2.50E+04	6.00E+00	1.04E-11	7.17E-12	2.33E-12	3.57E-13	2.58E-14	8.83E-16
5.05E+01	1.25E+04	2.50E+04	6.49E+00	3.29E-06	2.26E-06	7.34E-07	1.13E-07	8.16E-09	2.79E-10
5.88E+01	1.25E+04	2.50E+04	8.40E+00	5.55E-03	3.81E-03	1.24E-03	1.90E-04	1.38E-05	4.70E-07
6.87E+01	1.25E+04	2.50E+04	2.11E+01	6.33E-03	4.35E-03	1.41E-03	2.17E-04	1.57E-05	5.38E-07
8.06E+01	1.25E+04	2.50E+04	3.57E+01	4.93E-03	3.39E-03	1.10E-03	1.69E-04	1.22E-05	4.18E-07
9.49E+01	1.26E+04	2.50E+04	4.94E+01	3.69E-03	2.54E-03	8.23E-04	1.26E-04	9.15E-06	3.12E-07
1.12E+02	1.26E+04	2.50E+04	6.20E+01	2.83E-03	1.95E-03	6.33E-04	9.70E-05	7.03E-06	2.40E-07
1.33E+02	1.26E+04	2.50E+04	7.40E+01	2.23E-03	1.54E-03	4.98E-04	7.64E-05	5.54E-06	1.89E-07
1.57E+02	1.26E+04	2.50E+04	8.56E+01	1.79E-03	1.23E-03	4.00E-04	6.13E-05	4.44E-06	1.52E-07
1.87E+02	1.26E+04	2.50E+04	9.70E+01	1.45E-03	9.97E-04	3.24E-04	4.96E-05	3.60E-06	1.23E-07
2.23E+02	1.26E+04	2.50E+04	1.08E+02	1.18E-03	8.12E-04	2.64E-04	4.04E-05	2.93E-06	1.00E-07
2.66E+02	1.27E+04	2.50E+04	1.20E+02	9.66E-04	6.64E-04	2.15E-04	3.30E-05	2.39E-06	8.19E-08
3.17E+02	1.27E+04	2.50E+04	1.31E+02	7.90E-04	5.43E-04	1.76E-04	2.70E-05	1.96E-06	6.69E-08
3.79E+02	1.27E+04	2.50E+04	1.43E+02	6.47E-04	4.45E-04	1.44E-04	2.21E-05	1.60E-06	5.48E-08
4.54E+02	1.28E+04	2.50E+04	1.55E+02	5.30E-04	3.64E-04	1.18E-04	1.81E-05	1.31E-06	4.49E-08
5.43E+02	1.28E+04	2.50E+04	1.68E+02	4.33E-04	2.98E-04	9.66E-05	1.48E-05	1.07E-06	3.68E-08
6.50E+02	1.29E+04	2.50E+04	1.81E+02	3.54E-04	2.43E-04	7.89E-05	1.21E-05	8.77E-07	3.00E-08
7.79E+02	1.30E+04	2.50E+04	1.95E+02	2.89E-04	1.98E-04	6.44E-05	9.88E-06	7.15E-07	2.45E-08
9.33E+02	1.31E+04	2.50E+04	2.10E+02	2.35E-04	1.62E-04	5.24E-05	8.04E-06	5.82E-07	2.00E-08
1.12E+03	1.32E+04	2.50E+04	2.26E+02	1.91E-04	1.31E-04	4.26E-05	6.53E-06	4.73E-07	1.62E-08
1.34E+03	1.33E+04	2.50E+04	2.44E+02	1.55E-04	1.06E-04	3.45E-05	5.30E-06	3.84E-07	1.31E-08
1.61E+03	1.34E+04	2.50E+04	2.64E+02	1.25E-04	8.60E-05	2.79E-05	4.28E-06	3.10E-07	1.06E-08
1.93E+03	1.36E+04	2.50E+04	2.87E+02	1.01E-04	6.92E-05	2.25E-05	3.45E-06	2.50E-07	8.51E-09
2.32E+03	1.39E+04	2.50E+04	3.13E+02	8.09E-05	5.56E-05	1.80E-05	2.77E-06	2.00E-07	6.86E-09
2.78E+03	1.41E+04	2.50E+04	3.42E+02	6.47E-05	4.45E-05	1.44E-05	2.21E-06	1.60E-07	5.49E-09
3.34E+03	1.45E+04	2.50E+04	3.75E+02	5.16E-05	3.55E-05	1.15E-05	1.77E-06	1.28E-07	4.38E-09
4.01E+03	1.49E+04	2.50E+04	4.12E+02	4.10E-05	2.82E-05	9.15E-06	1.40E-06	1.02E-07	3.49E-09
4.81E+03	1.53E+04	2.50E+04	4.55E+02	3.25E-05	2.23E-05	7.25E-06	1.11E-06	8.06E-08	2.77E-09
5.78E+03	1.59E+04	2.50E+04	5.03E+02	2.57E-05	1.77E-05	5.73E-06	8.79E-07	6.37E-08	2.18E-09
6.94E+03	1.66E+04	2.50E+04	5.57E+02	2.03E-05	1.39E-05	4.52E-06	6.94E-07	5.02E-08	1.72E-09
8.33E+03	1.74E+04	2.50E+04	6.18E+02	1.60E-05	1.10E-05	3.56E-06	5.46E-07	3.96E-08	1.35E-09
1.00E+04	1.84E+04	2.50E+04	6.87E+02	1.25E-05	8.62E-06	2.80E-06	4.29E-07	3.11E-08	1.07E-09

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time averaged (tav = 900. 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	1.25E+04	2.50E+04	2.97E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1.95E+00	1.25E+04	2.50E+04	4.25E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2.91E+00	1.25E+04	2.50E+04	8.21E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3.86E+00	1.25E+04	2.50E+04	1.22E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4.81E+00	1.25E+04	2.50E+04	1.61E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
5.77E+00	1.25E+04	2.50E+04	2.01E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
6.72E+00	1.25E+04	2.50E+04	2.40E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
7.67E+00	1.25E+04	2.50E+04	2.80E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

8.63E+00	1.25E+04	2.50E+04	3.20E+00	5.75E-44	3.92E-44	1.26E-44	1.40E-45	0.00E+00	0.00E+00
9.58E+00	1.25E+04	2.50E+04	3.59E+00	3.04E-36	2.09E-36	6.79E-37	1.04E-37	7.54E-39	2.58E-40
1.05E+01	1.25E+04	2.50E+04	3.99E+00	3.13E-30	2.15E-30	6.97E-31	1.07E-31	7.75E-33	2.65E-34
1.07E+01	1.25E+04	2.50E+04	4.00E+00	3.15E-30	2.16E-30	7.02E-31	1.08E-31	7.80E-33	2.67E-34
1.10E+01	1.25E+04	2.50E+04	4.01E+00	3.18E-30	2.19E-30	7.10E-31	1.09E-31	7.88E-33	2.69E-34
1.13E+01	1.25E+04	2.50E+04	4.02E+00	3.25E-30	2.24E-30	7.26E-31	1.11E-31	8.06E-33	2.76E-34
1.17E+01	1.25E+04	2.50E+04	4.04E+00	3.39E-30	2.33E-30	7.56E-31	1.16E-31	8.40E-33	2.88E-34
1.21E+01	1.25E+04	2.50E+04	4.06E+00	3.64E-30	2.50E-30	8.12E-31	1.24E-31	9.01E-33	3.08E-34
1.26E+01	1.25E+04	2.50E+04	4.09E+00	4.08E-30	2.80E-30	9.10E-31	1.40E-31	1.01E-32	3.45E-34
1.33E+01	1.25E+04	2.50E+04	4.12E+00	4.88E-30	3.36E-30	1.09E-30	1.67E-31	1.21E-32	4.14E-34
1.40E+01	1.25E+04	2.50E+04	4.16E+00	6.43E-30	4.42E-30	1.44E-30	2.20E-31	1.59E-32	5.46E-34
1.50E+01	1.25E+04	2.50E+04	4.21E+00	9.76E-30	6.71E-30	2.18E-30	3.34E-31	2.42E-32	8.26E-34
1.61E+01	1.25E+04	2.50E+04	4.27E+00	1.81E-29	1.24E-29	4.04E-30	6.20E-31	4.49E-32	1.53E-33
1.74E+01	1.25E+04	2.50E+04	4.34E+00	4.49E-29	3.09E-29	1.00E-29	1.54E-30	1.11E-31	3.81E-33
1.90E+01	1.25E+04	2.50E+04	4.43E+00	1.68E-28	1.15E-28	3.74E-29	5.74E-30	4.16E-31	1.42E-32
2.09E+01	1.25E+04	2.50E+04	4.53E+00	1.11E-27	7.60E-28	2.47E-28	3.79E-29	2.74E-30	9.38E-32
2.32E+01	1.25E+04	2.50E+04	4.67E+00	1.59E-26	1.09E-26	3.54E-27	5.42E-28	3.93E-29	1.34E-30
2.59E+01	1.25E+04	2.50E+04	4.83E+00	6.37E-25	4.38E-25	1.42E-25	2.18E-26	1.58E-27	5.38E-29
2.92E+01	1.25E+04	2.50E+04	5.04E+00	9.52E-23	6.54E-23	2.12E-23	3.26E-24	2.36E-25	8.05E-27
3.32E+01	1.25E+04	2.50E+04	5.29E+00	1.81E-19	1.24E-19	4.04E-20	6.19E-21	4.49E-22	1.54E-23
3.79E+01	1.25E+04	2.50E+04	5.61E+00	3.77E-15	2.59E-15	8.41E-16	1.29E-16	9.34E-18	3.19E-19
4.37E+01	1.25E+04	2.50E+04	6.00E+00	3.22E-10	2.21E-10	7.19E-11	1.10E-11	7.98E-13	2.73E-14
5.05E+01	1.25E+04	2.50E+04	6.49E+00	1.66E-05	1.14E-05	3.69E-06	5.66E-07	4.10E-08	1.40E-09
5.88E+01	1.25E+04	2.50E+04	8.40E+00	5.50E-03	3.78E-03	1.23E-03	1.88E-04	1.36E-05	4.66E-07
6.87E+01	1.25E+04	2.50E+04	2.11E+01	5.02E-03	3.45E-03	1.12E-03	1.72E-04	1.25E-05	4.27E-07
8.06E+01	1.25E+04	2.50E+04	3.57E+01	3.43E-03	2.36E-03	7.66E-04	1.18E-04	8.51E-06	2.91E-07
9.49E+01	1.26E+04	2.50E+04	4.94E+01	2.53E-03	1.74E-03	5.64E-04	8.65E-05	6.26E-06	2.14E-07
1.12E+02	1.26E+04	2.50E+04	6.20E+01	1.99E-03	1.37E-03	4.45E-04	6.82E-05	4.94E-06	1.69E-07
1.33E+02	1.26E+04	2.50E+04	7.40E+01	1.64E-03	1.12E-03	3.65E-04	5.60E-05	4.06E-06	1.39E-07
1.57E+02	1.26E+04	2.50E+04	8.56E+01	1.37E-03	9.41E-04	3.05E-04	4.68E-05	3.39E-06	1.17E-07
1.87E+02	1.26E+04	2.50E+04	9.70E+01	1.16E-03	7.94E-04	2.58E-04	3.95E-05	2.86E-06	9.80E-08
2.23E+02	1.26E+04	2.50E+04	1.08E+02	9.76E-04	6.71E-04	2.18E-04	3.34E-05	2.42E-06	8.29E-08
2.66E+02	1.27E+04	2.50E+04	1.20E+02	8.24E-04	5.66E-04	1.84E-04	2.82E-05	2.04E-06	6.98E-08
3.17E+02	1.27E+04	2.50E+04	1.31E+02	6.93E-04	4.77E-04	1.55E-04	2.37E-05	1.72E-06	5.87E-08
3.79E+02	1.27E+04	2.50E+04	1.43E+02	5.81E-04	3.99E-04	1.30E-04	1.99E-05	1.44E-06	4.92E-08
4.54E+02	1.28E+04	2.50E+04	1.55E+02	4.85E-04	3.33E-04	1.08E-04	1.66E-05	1.20E-06	4.11E-08
5.43E+02	1.28E+04	2.50E+04	1.68E+02	4.03E-04	2.77E-04	9.00E-05	1.38E-05	1.00E-06	3.43E-08
6.50E+02	1.29E+04	2.50E+04	1.81E+02	3.34E-04	2.29E-04	7.45E-05	1.14E-05	8.28E-07	2.83E-08
7.79E+02	1.30E+04	2.50E+04	1.95E+02	2.75E-04	1.89E-04	6.14E-05	9.42E-06	6.82E-07	2.34E-08
9.33E+02	1.31E+04	2.50E+04	2.10E+02	2.26E-04	1.55E-04	5.05E-05	7.74E-06	5.61E-07	1.92E-08
1.12E+03	1.32E+04	2.50E+04	2.26E+02	1.85E-04	1.27E-04	4.13E-05	6.33E-06	4.59E-07	1.57E-08
1.34E+03	1.33E+04	2.50E+04	2.44E+02	1.51E-04	1.04E-04	3.37E-05	5.16E-06	3.74E-07	1.28E-08
1.61E+03	1.34E+04	2.50E+04	2.64E+02	1.23E-04	8.42E-05	2.73E-05	4.19E-06	3.04E-07	1.04E-08
1.93E+03	1.36E+04	2.50E+04	2.87E+02	9.91E-05	6.81E-05	2.21E-05	3.39E-06	2.46E-07	8.37E-09
2.32E+03	1.39E+04	2.50E+04	3.13E+02	7.98E-05	5.48E-05	1.78E-05	2.73E-06	1.98E-07	6.76E-09
2.78E+03	1.41E+04	2.50E+04	3.42E+02	6.40E-05	4.40E-05	1.43E-05	2.19E-06	1.59E-07	5.43E-09
3.34E+03	1.45E+04	2.50E+04	3.75E+02	5.11E-05	3.51E-05	1.14E-05	1.75E-06	1.27E-07	4.34E-09
4.01E+03	1.49E+04	2.50E+04	4.12E+02	4.07E-05	2.80E-05	9.09E-06	1.39E-06	1.01E-07	3.47E-09
4.81E+03	1.53E+04	2.50E+04	4.55E+02	3.23E-05	2.22E-05	7.21E-06	1.11E-06	8.01E-08	2.76E-09
5.78E+03	1.59E+04	2.50E+04	5.03E+02	2.56E-05	1.76E-05	5.71E-06	8.75E-07	6.34E-08	2.17E-09
6.94E+03	1.66E+04	2.50E+04	5.57E+02	2.02E-05	1.39E-05	4.50E-06	6.91E-07	5.00E-08	1.72E-09
8.33E+03	1.74E+04	2.50E+04	6.18E+02	1.59E-05	1.09E-05	3.55E-06	5.44E-07	3.94E-08	1.35E-09
1.00E+04	1.84E+04	2.50E+04	6.87E+02	1.25E-05	8.60E-06	2.79E-06	4.28E-07	3.10E-08	1.07E-09

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time averaged (tav = 900. s) volume concentration: concentration in the z = 2.00 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	1.25E+04	2.50E+04	2.97E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1.95E+00	1.25E+04	2.50E+04	4.25E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2.91E+00	1.25E+04	2.50E+04	8.21E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3.86E+00	1.25E+04	2.50E+04	1.22E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4.81E+00	1.25E+04	2.50E+04	1.61E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
5.77E+00	1.25E+04	2.50E+04	2.01E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
6.72E+00	1.25E+04	2.50E+04	2.40E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
7.67E+00	1.25E+04	2.50E+04	2.80E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
8.63E+00	1.25E+04	2.50E+04	3.20E+00	1.20E-38	8.22E-39	2.67E-39	4.09E-40	2.96E-41	1.02E-42
9.58E+00	1.25E+04	2.50E+04	3.59E+00	5.62E-32	3.86E-32	1.25E-32	1.92E-33	1.39E-34	4.76E-36
1.05E+01	1.25E+04	2.50E+04	3.99E+00	9.41E-27	6.47E-27	2.10E-27	3.22E-28	2.33E-29	7.97E-31
1.07E+01	1.25E+04	2.50E+04	4.00E+00	9.47E-27	6.51E-27	2.11E-27	3.24E-28	2.35E-29	8.04E-31
1.10E+01	1.25E+04	2.50E+04	4.01E+00	9.56E-27	6.57E-27	2.13E-27	3.27E-28	2.37E-29	8.09E-31
1.13E+01	1.25E+04	2.50E+04	4.02E+00	9.75E-27	6.70E-27	2.18E-27	3.34E-28	2.42E-29	8.27E-31
1.17E+01	1.25E+04	2.50E+04	4.04E+00	1.01E-26	6.96E-27	2.26E-27	3.47E-28	2.51E-29	8.60E-31
1.21E+01	1.25E+04	2.50E+04	4.06E+00	1.08E-26	7.43E-27	2.41E-27	3.70E-28	2.68E-29	9.16E-31
1.26E+01	1.25E+04	2.50E+04	4.09E+00	1.20E-26	8.26E-27	2.68E-27	4.11E-28	2.98E-29	1.02E-30
1.33E+01	1.25E+04	2.50E+04	4.12E+00	1.42E-26	9.76E-27	3.17E-27	4.86E-28	3.52E-29	1.20E-30
1.40E+01	1.25E+04	2.50E+04	4.16E+00	1.84E-26	1.26E-26	4.10E-27	6.28E-28	4.55E-29	1.56E-30
1.50E+01	1.25E+04	2.50E+04	4.21E+00	2.70E-26	1.86E-26	6.03E-27	9.25E-28	6.70E-29	2.29E-30
1.61E+01	1.25E+04	2.50E+04	4.27E+00	4.81E-26	3.30E-26	1.07E-26	1.64E-27	1.19E-28	4.07E-30
1.74E+01	1.25E+04	2.50E+04	4.34E+00	1.12E-25	7.69E-26	2.50E-26	3.83E-27	2.77E-28	9.48E-30
1.90E+01	1.25E+04	2.50E+04	4.43E+00	3.81E-25	2.62E-25	8.49E-26	1.30E-26	9.43E-28	3.23E-29
2.09E+01	1.25E+04	2.50E+04	4.53E+00	2.20E-24	1.51E-24	4.90E-25	7.52E-26	5.44E-27	1.86E-28
2.32E+01	1.25E+04	2.50E+04	4.67E+00	2.60E-23	1.79E-23	5.80E-24	8.90E-25	6.44E-26	2.20E-27
2.59E+01	1.25E+04	2.50E+04	4.83E+00	7.96E-22	5.47E-22	1.78E-22	2.72E-23	1.97E-24	6.73E-26
2.92E+01	1.25E+04	2.50E+04	5.04E+00	8.13E-20	5.58E-20	1.81E-20	2.78E-21	2.01E-22	6.87E-24
3.32E+01	1.25E+04	2.50E+04	5.29E+00	7.81E-17	5.37E-17	1.74E-17	2.67E-18	1.94E-19	6.63E-21
3.79E+01	1.25E+04	2.50E+04	5.61E+00	5.84E-13	4.01E-13	1.30E-13	2.00E-14	1.45E-15	4.94E-17
4.37E+01	1.25E+04	2.50E+04	6.00E+00	1.27E-08	8.70E-09	2.82E-09	4.33E-10	3.14E-11	1.07E-12
5.05E+01	1.25E+04	2.50E+04	6.49E+00	1.12E-04	7.72E-05	2.51E-05	3.84E-06	2.78E-07	9.52E-09
5.88E+01	1.25E+04	2.50E+04	8.40E+00	5.11E-03	3.51E-03	1.14E-03	1.75E-04	1.27E-05	4.33E-07
6.87E+01	1.25E+04	2.50E+04	2.11E+01	2.41E-03	1.66E-03	5.38E-04	8.26E-05	5.98E-06	2.05E-07
8.06E+01	1.25E+04	2.50E+04	3.57E+01	1.14E-03	7.87E-04	2.55E-04	3.92E-05	2.84E-06	9.70E-08
9.49E+01	1.26E+04	2.50E+04	4.94E+01	8.09E-04	5.56E-04	1.80E-04	2.77E-05	2.00E-06	6.84E-08
1.12E+02	1.26E+04	2.50E+04	6.20E+01	6.92E-04	4.75E-04	1.54E-04	2.37E-05	1.71E-06	5.87E-08
1.33E+02	1.26E+04	2.50E+04	7.40E+01	6.42E-04	4.41E-04	1.43E-04	2.20E-05	1.59E-06	5.45E-08
1.57E+02	1.26E+04	2.50E+04	8.56E+01	6.12E-04	4.21E-04	1.37E-04	2.09E-05	1.52E-06	5.21E-08
1.87E+02	1.26E+04	2.50E+04	9.70E+01	5.83E-04	4.01E-04	1.30E-04	2.00E-05	1.45E-06	4.95E-08

2.23E+02	1.26E+04	2.50E+04	1.08E+02	5.50E-04	3.78E-04	1.23E-04	1.88E-05	1.36E-06	4.68E-08
2.66E+02	1.27E+04	2.50E+04	1.20E+02	5.12E-04	3.52E-04	1.14E-04	1.75E-05	1.27E-06	4.34E-08
3.17E+02	1.27E+04	2.50E+04	1.31E+02	4.68E-04	3.22E-04	1.05E-04	1.60E-05	1.16E-06	3.97E-08
3.79E+02	1.27E+04	2.50E+04	1.43E+02	4.21E-04	2.90E-04	9.40E-05	1.44E-05	1.04E-06	3.57E-08
4.54E+02	1.28E+04	2.50E+04	1.55E+02	3.73E-04	2.56E-04	8.32E-05	1.28E-05	9.25E-07	3.16E-08
5.43E+02	1.28E+04	2.50E+04	1.68E+02	3.25E-04	2.24E-04	7.26E-05	1.11E-05	8.07E-07	2.77E-08
6.50E+02	1.29E+04	2.50E+04	1.81E+02	2.80E-04	1.93E-04	6.26E-05	9.60E-06	6.95E-07	2.38E-08
7.79E+02	1.30E+04	2.50E+04	1.95E+02	2.39E-04	1.64E-04	5.33E-05	8.18E-06	5.92E-07	2.03E-08
9.33E+02	1.31E+04	2.50E+04	2.10E+02	2.02E-04	1.39E-04	4.50E-05	6.90E-06	5.00E-07	1.71E-08
1.12E+03	1.32E+04	2.50E+04	2.26E+02	1.69E-04	1.16E-04	3.76E-05	5.77E-06	4.18E-07	1.43E-08
1.34E+03	1.33E+04	2.50E+04	2.44E+02	1.40E-04	9.61E-05	3.12E-05	4.79E-06	3.47E-07	1.19E-08
1.61E+03	1.34E+04	2.50E+04	2.64E+02	1.15E-04	7.92E-05	2.57E-05	3.94E-06	2.86E-07	9.77E-09
1.93E+03	1.36E+04	2.50E+04	2.87E+02	9.42E-05	6.48E-05	2.10E-05	3.22E-06	2.34E-07	7.96E-09
2.32E+03	1.39E+04	2.50E+04	3.13E+02	7.66E-05	5.27E-05	1.71E-05	2.62E-06	1.90E-07	6.49E-09
2.78E+03	1.41E+04	2.50E+04	3.42E+02	6.19E-05	4.26E-05	1.38E-05	2.12E-06	1.53E-07	5.25E-09
3.34E+03	1.45E+04	2.50E+04	3.75E+02	4.98E-05	3.42E-05	1.11E-05	1.70E-06	1.23E-07	4.23E-09
4.01E+03	1.49E+04	2.50E+04	4.12E+02	3.98E-05	2.74E-05	8.89E-06	1.36E-06	9.87E-08	3.39E-09
4.81E+03	1.53E+04	2.50E+04	4.55E+02	3.17E-05	2.18E-05	7.08E-06	1.09E-06	7.87E-08	2.71E-09
5.78E+03	1.59E+04	2.50E+04	5.03E+02	2.52E-05	1.73E-05	5.62E-06	8.62E-07	6.25E-08	2.14E-09
6.94E+03	1.66E+04	2.50E+04	5.57E+02	2.00E-05	1.37E-05	4.45E-06	6.83E-07	4.95E-08	1.70E-09
8.33E+03	1.74E+04	2.50E+04	6.18E+02	1.58E-05	1.08E-05	3.52E-06	5.39E-07	3.90E-08	1.34E-09
1.00E+04	1.84E+04	2.50E+04	6.87E+02	1.24E-05	8.53E-06	2.77E-06	4.25E-07	3.08E-08	1.06E-09

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time averaged (tav = 900. s) volume concentration: concentration in the z = 4.00 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	1.25E+04	2.50E+04	2.97E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1.95E+00	1.25E+04	2.50E+04	4.25E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2.91E+00	1.25E+04	2.50E+04	8.21E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3.86E+00	1.25E+04	2.50E+04	1.22E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4.81E+00	1.25E+04	2.50E+04	1.61E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
5.77E+00	1.25E+04	2.50E+04	2.01E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
6.72E+00	1.25E+04	2.50E+04	2.40E+00	1.18E-43	8.13E-44	2.66E-44	4.20E-45	0.00E+00	0.00E+00
7.67E+00	1.25E+04	2.50E+04	2.80E+00	2.57E-35	1.77E-35	5.74E-36	8.80E-37	6.37E-38	2.18E-39
8.63E+00	1.25E+04	2.50E+04	3.20E+00	4.15E-29	2.85E-29	9.26E-30	1.42E-30	1.03E-31	3.52E-33
9.58E+00	1.25E+04	2.50E+04	3.59E+00	2.59E-24	1.78E-24	5.78E-25	8.87E-26	6.42E-27	2.20E-28
1.05E+01	1.25E+04	2.50E+04	3.99E+00	1.68E-20	1.15E-20	3.75E-21	5.75E-22	4.16E-23	1.42E-24
1.07E+01	1.25E+04	2.50E+04	4.00E+00	1.69E-20	1.16E-20	3.76E-21	5.77E-22	4.18E-23	1.43E-24
1.10E+01	1.25E+04	2.50E+04	4.01E+00	1.70E-20	1.17E-20	3.79E-21	5.81E-22	4.21E-23	1.44E-24
1.13E+01	1.25E+04	2.50E+04	4.02E+00	1.73E-20	1.19E-20	3.85E-21	5.91E-22	4.28E-23	1.46E-24
1.17E+01	1.25E+04	2.50E+04	4.04E+00	1.78E-20	1.23E-20	3.98E-21	6.10E-22	4.42E-23	1.51E-24
1.21E+01	1.25E+04	2.50E+04	4.06E+00	1.88E-20	1.29E-20	4.20E-21	6.44E-22	4.67E-23	1.60E-24
1.26E+01	1.25E+04	2.50E+04	4.09E+00	2.06E-20	1.42E-20	4.59E-21	7.05E-22	5.10E-23	1.74E-24
1.33E+01	1.25E+04	2.50E+04	4.12E+00	2.37E-20	1.63E-20	5.29E-21	8.11E-22	5.88E-23	2.01E-24
1.40E+01	1.25E+04	2.50E+04	4.16E+00	2.95E-20	2.03E-20	6.58E-21	1.01E-21	7.30E-23	2.50E-24
1.50E+01	1.25E+04	2.50E+04	4.21E+00	4.09E-20	2.81E-20	9.13E-21	1.40E-21	1.01E-22	3.47E-24
1.61E+01	1.25E+04	2.50E+04	4.27E+00	6.68E-20	4.59E-20	1.49E-20	2.28E-21	1.65E-22	5.66E-24
1.74E+01	1.25E+04	2.50E+04	4.34E+00	1.37E-19	9.41E-20	3.06E-20	4.69E-21	3.39E-22	1.16E-23
1.90E+01	1.25E+04	2.50E+04	4.43E+00	3.88E-19	2.67E-19	8.65E-20	1.33E-20	9.61E-22	3.29E-23
2.09E+01	1.25E+04	2.50E+04	4.53E+00	1.72E-18	1.18E-18	3.83E-19	5.87E-20	4.25E-21	1.45E-22
2.32E+01	1.25E+04	2.50E+04	4.67E+00	1.39E-17	9.54E-18	3.10E-18	4.75E-19	3.44E-20	1.18E-21
2.59E+01	1.25E+04	2.50E+04	4.83E+00	2.47E-16	1.70E-16	5.52E-17	8.47E-18	6.13E-19	2.09E-20
2.92E+01	1.25E+04	2.50E+04	5.04E+00	1.18E-14	8.11E-15	2.63E-15	4.04E-16	2.93E-17	9.99E-19
3.32E+01	1.25E+04	2.50E+04	5.29E+00	3.02E-12	2.08E-12	6.74E-13	1.03E-13	7.49E-15	2.56E-16
3.79E+01	1.25E+04	2.50E+04	5.61E+00	3.16E-09	2.17E-09	7.06E-10	1.08E-10	7.84E-12	2.68E-13
4.37E+01	1.25E+04	2.50E+04	6.00E+00	5.03E-06	3.46E-06	1.12E-06	1.72E-07	1.25E-08	4.26E-10
5.05E+01	1.25E+04	2.50E+04	6.49E+00	1.68E-03	1.15E-03	3.75E-04	5.75E-05	4.16E-06	1.42E-07
5.88E+01	1.25E+04	2.50E+04	8.40E+00	2.68E-03	1.84E-03	5.97E-04	9.15E-05	6.63E-06	2.26E-07
6.87E+01	1.25E+04	2.50E+04	2.11E+01	9.21E-05	6.33E-05	2.06E-05	3.15E-06	2.28E-07	7.83E-09
8.06E+01	1.25E+04	2.50E+04	3.57E+01	1.24E-05	8.52E-06	2.76E-06	4.24E-07	3.07E-08	1.05E-09
9.49E+01	1.26E+04	2.50E+04	4.94E+01	8.15E-06	5.60E-06	1.82E-06	2.79E-07	2.02E-08	6.89E-10
1.12E+02	1.26E+04	2.50E+04	6.20E+01	9.90E-06	6.81E-06	2.21E-06	3.39E-07	2.46E-08	8.40E-10
1.33E+02	1.26E+04	2.50E+04	7.40E+01	1.52E-05	1.05E-05	3.39E-06	5.20E-07	3.77E-08	1.29E-09
1.57E+02	1.26E+04	2.50E+04	8.56E+01	2.44E-05	1.68E-05	5.44E-06	8.34E-07	6.04E-08	2.07E-09
1.87E+02	1.26E+04	2.50E+04	9.70E+01	3.79E-05	2.61E-05	8.47E-06	1.30E-06	9.40E-08	3.22E-09
2.23E+02	1.26E+04	2.50E+04	1.08E+02	5.56E-05	3.82E-05	1.24E-05	1.90E-06	1.38E-07	4.72E-09
2.66E+02	1.27E+04	2.50E+04	1.20E+02	7.63E-05	5.24E-05	1.70E-05	2.61E-06	1.89E-07	6.47E-09
3.17E+02	1.27E+04	2.50E+04	1.31E+02	9.75E-05	6.70E-05	2.18E-05	3.34E-06	2.42E-07	8.26E-09
3.79E+02	1.27E+04	2.50E+04	1.43E+02	1.16E-04	8.00E-05	2.60E-05	3.98E-06	2.88E-07	9.85E-09
4.54E+02	1.28E+04	2.50E+04	1.55E+02	1.30E-04	8.95E-05	2.91E-05	4.46E-06	3.23E-07	1.10E-08
5.43E+02	1.28E+04	2.50E+04	1.68E+02	1.38E-04	9.49E-05	3.08E-05	4.73E-06	3.42E-07	1.17E-08
6.50E+02	1.29E+04	2.50E+04	1.81E+02	1.40E-04	9.60E-05	3.12E-05	4.78E-06	3.46E-07	1.18E-08
7.79E+02	1.30E+04	2.50E+04	1.95E+02	1.36E-04	9.32E-05	3.03E-05	4.64E-06	3.36E-07	1.15E-08
9.33E+02	1.31E+04	2.50E+04	2.10E+02	1.27E-04	8.75E-05	2.84E-05	4.36E-06	3.16E-07	1.08E-08
1.12E+03	1.32E+04	2.50E+04	2.26E+02	1.16E-04	7.98E-05	2.59E-05	3.97E-06	2.88E-07	9.85E-09
1.34E+03	1.33E+04	2.50E+04	2.44E+02	1.03E-04	7.10E-05	2.30E-05	3.53E-06	2.56E-07	8.77E-09
1.61E+03	1.34E+04	2.50E+04	2.64E+02	9.01E-05	6.19E-05	2.01E-05	3.08E-06	2.23E-07	7.64E-09
1.93E+03	1.36E+04	2.50E+04	2.87E+02	7.71E-05	5.30E-05	1.72E-05	2.64E-06	1.91E-07	6.52E-09
2.32E+03	1.39E+04	2.50E+04	3.13E+02	6.51E-05	4.47E-05	1.45E-05	2.23E-06	1.61E-07	5.52E-09
2.78E+03	1.41E+04	2.50E+04	3.42E+02	5.42E-05	3.73E-05	1.21E-05	1.86E-06	1.34E-07	4.60E-09
3.34E+03	1.45E+04	2.50E+04	3.75E+02	4.47E-05	3.07E-05	9.97E-06	1.53E-06	1.11E-07	3.80E-09
4.01E+03	1.49E+04	2.50E+04	4.12E+02	3.65E-05	2.51E-05	8.14E-06	1.25E-06	9.04E-08	3.11E-09
4.81E+03	1.53E+04	2.50E+04	4.55E+02	2.96E-05	2.03E-05	6.59E-06	1.01E-06	7.32E-08	2.52E-09
5.78E+03	1.59E+04	2.50E+04	5.03E+02	2.38E-05	1.63E-05	5.31E-06	8.14E-07	5.89E-08	2.02E-09
6.94E+03	1.66E+04	2.50E+04	5.57E+02	1.90E-05	1.31E-05	4.25E-06	6.51E-07	4.72E-08	1.62E-09
8.33E+03	1.74E+04	2.50E+04	6.18E+02	1.52E-05	1.04E-05	3.38E-06	5.19E-07	3.76E-08	1.29E-09
1.00E+04	1.84E+04	2.50E+04	6.87E+02	1.20E-05	8.27E-06	2.69E-06	4.12E-07	2.98E-08	1.02E-09

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time averaged (tav = 900. 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	5.00E+00	1.00E+00	1.25E+04	2.50E+04

1.95E+00	9.92E+00	6.38E-01	1.25E+04	2.50E+04
2.91E+00	1.18E+01	2.14E-01	1.25E+04	2.50E+04
3.86E+00	1.31E+01	1.01E-01	1.25E+04	2.50E+04
4.81E+00	1.40E+01	5.84E-02	1.25E+04	2.50E+04
5.77E+00	1.48E+01	3.78E-02	1.25E+04	2.50E+04
6.72E+00	1.53E+01	2.64E-02	1.25E+04	2.50E+04
7.67E+00	1.58E+01	1.95E-02	1.25E+04	2.50E+04
8.63E+00	1.61E+01	1.49E-02	1.25E+04	2.50E+04
9.58E+00	1.62E+01	1.18E-02	1.25E+04	2.50E+04
1.05E+01	1.63E+01	9.58E-03	1.25E+04	2.50E+04
1.07E+01	1.63E+01	9.56E-03	1.25E+04	2.50E+04
1.10E+01	1.63E+01	9.53E-03	1.25E+04	2.50E+04
1.13E+01	1.63E+01	9.49E-03	1.25E+04	2.50E+04
1.17E+01	1.63E+01	9.45E-03	1.25E+04	2.50E+04
1.21E+01	1.63E+01	9.40E-03	1.25E+04	2.50E+04
1.26E+01	1.63E+01	9.34E-03	1.25E+04	2.50E+04
1.33E+01	1.62E+01	9.27E-03	1.25E+04	2.50E+04
1.40E+01	1.62E+01	9.18E-03	1.25E+04	2.50E+04
1.50E+01	1.62E+01	9.08E-03	1.25E+04	2.50E+04
1.61E+01	1.61E+01	8.95E-03	1.25E+04	2.50E+04
1.74E+01	1.60E+01	8.80E-03	1.25E+04	2.50E+04
1.90E+01	1.58E+01	8.63E-03	1.25E+04	2.50E+04
2.09E+01	1.56E+01	8.42E-03	1.25E+04	2.50E+04
2.32E+01	1.52E+01	8.17E-03	1.25E+04	2.50E+04
2.59E+01	1.47E+01	7.89E-03	1.25E+04	2.50E+04
2.92E+01	1.41E+01	7.56E-03	1.25E+04	2.50E+04
3.32E+01	1.31E+01	7.19E-03	1.25E+04	2.50E+04
3.79E+01	1.17E+01	6.78E-03	1.25E+04	2.50E+04
4.37E+01	9.62E+00	6.33E-03	1.25E+04	2.50E+04
5.05E+01	6.56E+00	5.84E-03	1.25E+04	2.50E+04
5.88E+01	0.00E+00	5.55E-03	1.25E+04	2.50E+04
6.87E+01	0.00E+00	6.33E-03	1.25E+04	2.50E+04
8.06E+01	0.00E+00	4.93E-03	1.25E+04	2.50E+04
9.49E+01	0.00E+00	3.69E-03	1.26E+04	2.50E+04
1.12E+02	0.00E+00	2.83E-03	1.26E+04	2.50E+04
1.33E+02	0.00E+00	2.23E-03	1.26E+04	2.50E+04
1.57E+02	0.00E+00	1.79E-03	1.26E+04	2.50E+04
1.87E+02	0.00E+00	1.45E-03	1.26E+04	2.50E+04
2.23E+02	0.00E+00	1.18E-03	1.26E+04	2.50E+04
2.66E+02	0.00E+00	9.66E-04	1.27E+04	2.50E+04
3.17E+02	0.00E+00	7.90E-04	1.27E+04	2.50E+04
3.79E+02	0.00E+00	6.47E-04	1.27E+04	2.50E+04
4.54E+02	0.00E+00	5.30E-04	1.28E+04	2.50E+04
5.43E+02	0.00E+00	4.33E-04	1.28E+04	2.50E+04
6.50E+02	0.00E+00	3.54E-04	1.29E+04	2.50E+04
7.79E+02	0.00E+00	2.89E-04	1.30E+04	2.50E+04
9.33E+02	0.00E+00	2.35E-04	1.31E+04	2.50E+04
1.12E+03	0.00E+00	1.91E-04	1.32E+04	2.50E+04
1.34E+03	0.00E+00	1.55E-04	1.33E+04	2.50E+04
1.61E+03	0.00E+00	1.25E-04	1.34E+04	2.50E+04
1.93E+03	0.00E+00	1.01E-04	1.36E+04	2.50E+04
2.32E+03	0.00E+00	8.09E-05	1.39E+04	2.50E+04
2.78E+03	0.00E+00	6.47E-05	1.41E+04	2.50E+04
3.34E+03	0.00E+00	5.16E-05	1.45E+04	2.50E+04
4.01E+03	0.00E+00	4.10E-05	1.49E+04	2.50E+04
4.81E+03	0.00E+00	3.25E-05	1.53E+04	2.50E+04
5.78E+03	0.00E+00	2.57E-05	1.59E+04	2.50E+04
6.94E+03	0.00E+00	2.03E-05	1.66E+04	2.50E+04
8.33E+03	0.00E+00	1.60E-05	1.74E+04	2.50E+04
1.00E+04	0.00E+00	1.25E-05	1.84E+04	2.50E+04

SLAB Example 2: Input File

```
    3
    1
.017031
2170.0
239.72
.82
1370840.
4294.0
682.8
2132.52
-32.98
239.72
56.0
.179
16200.
0.
.20
3600.
10000.
0.
1.
2.
4.
.01
10.0
4.50
298.0
50.0
4.
-1.
```

Output File

```
Ammonia pipeline release (aerosol) -- SLAB model

problem input

  idspl =          3
  ncalc =          1
  wms   =    .017031
  cps   =    2170.00
  tbp   =     239.72
  cmed0 =        .82
  dhe   =   1370840.
  cpsl  =    4294.00
  rhosl =     682.80
  spb   =    2132.52
  spc   =     -32.98
  ts    =     239.72
  qs    =      56.00
  as    =        .18
  tsd   =     16200.
  qtis  =        .00
  hs    =        .20
  tav   =    3600.00
  xffm  =   10000.00
  zp(1) =        .00
  zp(2) =       1.00
  zp(3) =       2.00
  zp(4) =       4.00
  z0    =    .010000
  za    =      10.00
  ua    =       4.50
  ta    =     298.00
  rh    =      50.00
  stab  =       4.00

release gas properties

  molecular weight of source gas (kg)              - wms   =  1.7031E-02
  vapor heat capacity, const. p.  (j/kg-k)         - cps   =  2.1700E+03
  temperature of source gas (k)                    - ts    =  2.3972E+02
  density of source gas (kg/m3)                    - rhos  =  8.6582E-01
  boiling point temperature                        - tbp   =  2.3972E+02
  liquid mass fraction                             - cmed0-  8.2000E-01
  liquid heat capacity (j/kg-k)                    - cpsl  =  4.2940E+03
  heat of vaporization (j/kg)                      - dhe   =  1.3708E+06
  liquid source density (kg/m3)                    - rhosl-  6.8280E+02
  saturation pressure constant                     - spa   =  1.0315E+01
  saturation pressure constant (k)                 - spb   =  2.1325E+03
  saturation pressure constant (k)                 - spc   = -3.2980E+01

spill characteristics

  spill type                                       - idspl-           3
  mass source rate (kg/s)                          - qs    =  5.6000E+01
  continuous source duration (s)                   - tsd   =  1.6200E+04
  continuous source mass (kg)                      - qtcs  =  9.0720E+05
  instantaneous source mass (kg)                   - qtis  =  0.0000E+00
  source area (m2)                                 - as    =  1.7900E-01
  vertical vapor velocity (m/s)                    - ws    =  6.5416E+01
  source half width (m)                            - bs    =  2.1154E-01
  source height (m)                                - hs    =  2.0000E-01
  horizontal vapor velocity (m/s)                  - us    =  0.0000E+00

field parameters

  concentration averaging time (s)                 - tav   =  3.6000E+03
  mixing layer height (m)                          - hmx   =  1.0400E+03
  maximum downwind distrace (m)                    - xffm  =  1.0000E+04
  concentration measurement height (m)             - zp(1)-  0.0000E+00
                                                   - zp(2)-  1.0000E+00
                                                   - zp(3)-  2.0000E+00
                                                   - zp(4)-  4.0000E+00

ambient meteorological properties

  molecular weight of ambient air (kg)             - wmae  =  2.8782E-02
  heat capacity of ambient air at const p. (j/kg-k)- cpaa  =  1.0144E+03
  density of ambient air (kg/m3)                   - rhoa  =  1.1770E+00
  ambient measurement height (m)                   - za    =  1.0000E+01
  ambient atmospheric pressure (pa=n/m2=j/m3)      - pa    =  1.0133E+05
  ambient wind speed (m/s)                         - ua    =  4.5000E+00
  ambient temperature (k)                          - ta    =  2.9800E+02
  relative humidity (percent)                      - rh    =  5.0000E+01
  ambient friction velocity (m/s)                  - uastr =  2.6746E-01
  atmospheric stability class value                - stab  =  4.0000E+00
  inverse monin-obukhov length (1/m)               - ala   =  0.0000E+00
  surface roughness height (m)                     - z0    =  1.0000E-02

additional parameters

  sub-step multiplier                              - ncalc =           1
  number of calculational sub-steps                - nssm  =           3
  acceleration of gravity (m/s2)                   - grav  =  9.8067E+00
  gas constant (j/mol- k)                          - rr    =  8.3143E+00
```

von karman constant - xk = 4.1000E-01

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instantaneous spatially averaged cloud parameters

x	zc	h	bb	b	bbx	bx	cv	rho	t	u	ua
1.00E+00	2.00E-01	4.23E-01	2.12E-01	1.90E-01	0.00E+00	0.00E+00	1.00E+00	-1.00E+00	-1.00E+00	0.00E+00	4.83E+00
1.45E+00	7.42E+00	2.32E+00	1.63E+00	3.41E-01	4.49E-01	4.49E-01	7.46E-01	-1.00E+00	-1.00E+00	1.50E+00	4.83E+00
1.90E+00	1.01E+01	4.22E+00	3.05E+00	4.92E-01	8.98E-01	8.98E-01	4.24E-01	-1.00E+00	-1.00E+00	2.12E+00	4.83E+00
2.35E+00	1.20E+01	6.12E+00	4.48E+00	6.43E-01	1.35E+00	1.35E+00	2.46E-01	-1.00E+00	-1.00E+00	2.60E+00	4.83E+00
2.80E+00	1.34E+01	8.02E+00	5.90E+00	7.94E-01	1.80E+00	1.80E+00	1.55E-01	-1.00E+00	-1.00E+00	3.01E+00	4.83E+00
3.25E+00	1.45E+01	9.92E+00	7.32E+00	9.44E-01	2.25E+00	2.25E+00	1.05E-01	-1.00E+00	-1.00E+00	3.36E+00	4.83E+00
3.70E+00	1.54E+01	1.18E+01	8.74E+00	1.10E+00	2.70E+00	2.70E+00	7.55E-02	-1.00E+00	-1.00E+00	3.68E+00	4.83E+00
4.14E+00	1.60E+01	1.37E+01	1.02E+01	1.25E+00	3.14E+00	3.14E+00	5.66E-02	-1.00E+00	-1.00E+00	3.98E+00	4.83E+00
4.59E+00	1.64E+01	1.56E+01	1.16E+01	1.40E+00	3.59E+00	3.59E+00	4.39E-02	-1.00E+00	-1.00E+00	4.25E+00	4.83E+00
5.04E+00	1.67E+01	1.75E+01	1.30E+01	1.55E+00	4.04E+00	4.04E+00	3.50E-02	-1.00E+00	-1.00E+00	4.51E+00	4.83E+00
5.49E+00	1.68E+01	1.94E+01	1.44E+01	1.70E+00	4.49E+00	4.49E+00	2.86E-02	1.23E+00	2.83E+02	4.75E+00	4.83E+00
5.61E+00	1.68E+01	1.94E+01	1.44E+01	1.70E+00	4.61E+00	4.61E+00	2.86E-02	1.23E+00	2.83E+02	4.75E+00	4.83E+00
5.76E+00	1.68E+01	1.94E+01	1.44E+01	1.70E+00	4.76E+00	4.76E+00	2.85E-02	1.23E+00	2.83E+02	4.75E+00	4.83E+00
5.93E+00	1.68E+01	1.94E+01	1.45E+01	1.70E+00	4.93E+00	4.93E+00	2.85E-02	1.23E+00	2.83E+02	4.75E+00	4.83E+00
6.15E+00	1.67E+01	1.94E+01	1.45E+01	1.70E+00	5.15E+00	5.15E+00	2.85E-02	1.23E+00	2.83E+02	4.75E+00	4.83E+00
6.41E+00	1.67E+01	1.94E+01	1.45E+01	1.70E+00	5.41E+00	5.41E+00	2.85E-02	1.23E+00	2.83E+02	4.75E+00	4.83E+00
6.73E+00	1.67E+01	1.94E+01	1.45E+01	1.70E+00	5.73E+00	5.72E+00	2.84E-02	1.23E+00	2.83E+02	4.75E+00	4.83E+00
7.11E+00	1.67E+01	1.94E+01	1.45E+01	1.70E+00	6.11E+00	6.11E+00	2.84E-02	1.23E+00	2.83E+02	4.75E+00	4.83E+00
7.58E+00	1.67E+01	1.94E+01	1.45E+01	1.70E+00	6.58E+00	6.58E+00	2.83E-02	1.23E+00	2.83E+02	4.75E+00	4.83E+00
8.15E+00	1.67E+01	1.94E+01	1.46E+01	1.70E+00	7.15E+00	7.15E+00	2.83E-02	1.23E+00	2.83E+02	4.75E+00	4.83E+00
8.85E+00	1.66E+01	1.94E+01	1.46E+01	1.70E+00	7.85E+00	7.85E+00	2.82E-02	1.23E+00	2.83E+02	4.75E+00	4.83E+00
9.70E+00	1.66E+01	1.95E+01	1.47E+01	1.70E+00	8.70E+00	8.70E+00	2.81E-02	1.23E+00	2.83E+02	4.75E+00	4.83E+00
1.07E+01	1.65E+01	1.95E+01	1.47E+01	1.70E+00	9.73E+00	9.73E+00	2.80E-02	1.23E+00	2.83E+02	4.75E+00	4.83E+00
1.20E+01	1.64E+01	1.95E+01	1.48E+01	1.70E+00	1.10E+01	1.10E+01	2.78E-02	1.23E+00	2.83E+02	4.75E+00	4.83E+00
1.35E+01	1.62E+01	1.95E+01	1.49E+01	1.70E+00	1.25E+01	1.25E+01	2.77E-02	1.23E+00	2.83E+02	4.75E+00	4.83E+00
1.54E+01	1.59E+01	1.95E+01	1.50E+01	1.70E+00	1.44E+01	1.44E+01	2.75E-02	1.23E+00	2.83E+02	4.75E+00	4.82E+00
1.76E+01	1.54E+01	1.96E+01	1.51E+01	1.70E+00	1.66E+01	1.66E+01	2.72E-02	1.23E+00	2.83E+02	4.74E+00	4.82E+00
2.04E+01	1.48E+01	1.96E+01	1.52E+01	1.70E+00	1.94E+01	1.94E+01	2.69E-02	1.23E+00	2.83E+02	4.74E+00	4.81E+00
2.37E+01	1.38E+01	1.97E+01	1.54E+01	1.70E+00	2.27E+01	2.27E+01	2.66E-02	1.23E+00	2.84E+02	4.73E+00	4.80E+00
2.78E+01	1.23E+01	1.98E+01	1.56E+01	1.70E+00	2.68E+01	2.68E+01	2.61E-02	1.23E+00	2.84E+02	4.73E+00	4.79E+00
3.27E+01	1.02E+01	2.00E+01	1.59E+01	1.70E+00	3.17E+01	3.17E+01	2.55E-02	1.23E+00	2.84E+02	4.71E+00	4.77E+00
3.87E+01	7.84E+00	1.62E+01	2.01E+01	2.12E+00	3.77E+01	3.77E+01	2.49E-02	1.23E+00	2.84E+02	4.72E+00	4.74E+00
4.61E+01	6.05E+00	1.27E+01	2.66E+01	2.75E+00	4.51E+01	4.51E+01	2.43E-02	1.22E+00	2.84E+02	4.67E+00	4.65E+00
5.50E+01	4.70E+00	1.03E+01	3.48E+01	3.55E+00	5.40E+01	5.40E+01	2.35E-02	1.22E+00	2.85E+02	4.55E+00	4.52E+00
6.58E+01	3.69E+00	8.56E+00	4.49E+01	4.53E+00	6.48E+01	6.48E+01	2.24E-02	1.22E+00	2.85E+02	4.45E+00	4.40E+00
7.90E+01	2.93E+00	7.36E+00	5.72E+01	5.70E+00	7.80E+01	7.80E+01	2.10E-02	1.22E+00	2.85E+02	4.36E+00	4.30E+00
9.51E+01	2.38E+00	6.60E+00	7.15E+01	7.05E+00	9.41E+01	9.41E+01	1.91E-02	1.22E+00	2.86E+02	4.29E+00	4.23E+00
1.15E+02	1.96E+00	6.18E+00	8.75E+01	8.54E+00	1.14E+02	1.14E+02	1.69E-02	1.22E+00	2.87E+02	4.24E+00	4.19E+00
1.38E+02	1.65E+00	6.05E+00	1.05E+02	1.01E+01	1.37E+02	1.37E+02	1.45E-02	1.21E+00	2.88E+02	4.22E+00	4.17E+00
1.67E+02	1.42E+00	6.20E+00	1.23E+02	1.18E+01	1.66E+02	1.66E+02	1.21E-02	1.20E+00	2.90E+02	4.21E+00	4.17E+00
2.03E+02	1.25E+00	6.63E+00	1.42E+02	1.34E+01	2.02E+02	2.02E+02	9.93E-03	1.20E+00	2.91E+02	4.21E+00	4.18E+00
2.45E+02	1.11E+00	7.32E+00	1.61E+02	1.51E+01	2.44E+02	2.44E+02	7.97E-03	1.19E+00	2.93E+02	4.21E+00	4.19E+00
2.97E+02	1.00E+00	8.30E+00	1.80E+02	1.67E+01	2.96E+02	2.96E+02	6.30E-03	1.19E+00	2.94E+02	4.21E+00	4.20E+00
3.61E+02	9.17E-01	9.60E+00	1.99E+02	1.83E+01	3.60E+02	3.60E+02	4.92E-03	1.19E+00	2.95E+02	4.24E+00	4.23E+00
4.38E+02	8.48E-01	1.13E+01	2.18E+02	1.98E+01	4.37E+02	4.37E+02	3.80E-03	1.18E+00	2.96E+02	4.27E+00	4.28E+00
5.32E+02	7.90E-01	1.34E+01	2.37E+02	2.12E+01	5.31E+02	5.31E+02	2.92E-03	1.18E+00	2.96E+02	4.33E+00	4.33E+00
6.46E+02	7.42E-01	1.60E+01	2.56E+02	2.26E+01	6.45E+02	6.45E+02	2.23E-03	1.18E+00	2.97E+02	4.39E+00	4.40E+00
7.85E+02	7.00E-01	1.92E+01	2.75E+02	2.39E+01	7.84E+02	7.84E+02	1.70E-03	1.18E+00	2.97E+02	4.47E+00	4.48E+00
9.54E+02	6.64E-01	2.31E+01	2.95E+02	2.53E+01	9.53E+02	9.53E+02	1.29E-03	1.18E+00	2.97E+02	4.55E+00	4.56E+00
1.16E+03	6.31E-01	2.78E+01	3.16E+02	2.66E+01	1.16E+03	1.16E+03	9.84E-04	1.18E+00	2.97E+02	4.64E+00	4.65E+00
1.41E+03	6.01E-01	3.35E+01	3.39E+02	2.79E+01	1.41E+03	1.41E+03	7.48E-04	1.18E+00	2.98E+02	4.74E+00	4.75E+00
1.71E+03	5.73E-01	4.03E+01	3.63E+02	2.92E+01	1.71E+03	1.71E+03	5.68E-04	1.18E+00	2.98E+02	4.84E+00	4.85E+00
2.09E+03	5.47E-01	4.84E+01	3.89E+02	3.06E+01	2.08E+03	2.08E+03	4.32E-04	1.18E+00	2.98E+02	4.94E+00	4.95E+00
2.54E+03	5.22E-01	5.80E+01	4.19E+02	3.21E+01	2.54E+03	2.54E+03	3.28E-04	1.18E+00	2.98E+02	5.04E+00	5.05E+00
3.09E+03	4.98E-01	6.94E+01	4.52E+02	3.37E+01	3.08E+03	3.08E+03	2.49E-04	1.18E+00	2.98E+02	5.14E+00	5.15E+00
3.75E+03	4.74E-01	8.27E+01	4.89E+02	3.54E+01	3.75E+03	3.75E+03	1.90E-04	1.18E+00	2.98E+02	5.24E+00	5.25E+00
4.57E+03	4.51E-01	9.84E+01	5.31E+02	3.72E+01	4.56E+03	4.56E+03	1.44E-04	1.18E+00	2.98E+02	5.35E+00	5.35E+00
5.55E+03	4.28E-01	1.17E+02	5.78E+02	3.91E+01	5.55E+03	5.55E+03	1.10E-04	1.18E+00	2.98E+02	5.45E+00	5.45E+00
6.76E+03	4.06E-01	1.38E+02	6.32E+02	4.13E+01	6.76E+03	6.75E+03	8.33E-05	1.18E+00	2.98E+02	5.54E+00	5.55E+00
8.22E+03	3.84E-01	1.62E+02	6.93E+02	4.36E+01	8.22E+03	8.22E+03	6.34E-05	1.18E+00	2.98E+02	5.64E+00	5.65E+00
1.00E+04	3.63E-01	1.91E+02	7.62E+02	4.62E+01	1.00E+04	1.00E+04	4.83E-05	1.18E+00	2.98E+02	5.73E+00	5.74E+00

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x	cm	cmv	cmda	cmw	cmwv	wc	vg	ug	w	v	vx
1.00E+00	1.00E+00	-1.00E+00	0.00E+00	0.00E+00	-1.00E+00	6.54E+01	0.00E+00	0.00E+00	-1.00E+00	-1.00E+00	0.00E+00
1.45E+00	6.35E-01	-1.00E+00	3.61E-01	3.72E-03	-1.00E+00	4.47E+01	0.00E+00	0.00E+00	-1.00E+00	-1.00E+00	0.00E+00
1.90E+00	3.03E-01	-1.00E+00	6.90E-01	7.11E-03	-1.00E+00	3.62E+01	0.00E+00	0.00E+00	-1.00E+00	-1.00E+00	0.00E+00
2.35E+00	1.62E-01	-1.00E+00	8.29E-01	8.55E-03	-1.00E+00	2.96E+01	0.00E+00	0.00E+00	-1.00E+00	-1.00E+00	0.00E+00
2.80E+00	9.81E-02	-1.00E+00	8.93E-01	9.20E-03	-1.00E+00	2.40E+01	0.00E+00	0.00E+00	-1.00E+00	-1.00E+00	0.00E+00
3.25E+00	6.51E-02	-1.00E+00	9.25E-01	9.54E-03	-1.00E+00	1.92E+01	0.00E+00	0.00E+00	-1.00E+00	-1.00E+00	0.00E+00
3.70E+00	4.61E-02	-1.00E+00	9.44E-01	9.74E-03	-1.00E+00	1.47E+01	0.00E+00	0.00E+00	-1.00E+00	-1.00E+00	0.00E+00
4.14E+00	3.43E-02	-1.00E+00	9.56E-01	9.86E-03	-1.00E+00	1.07E+01	0.00E+00	0.00E+00	-1.00E+00	-1.00E+00	0.00E+00
4.59E+00	2.65E-02	-1.00E+00	9.64E-01	9.94E-03	-1.00E+00	6.91E+00	0.00E+00	0.00E+00	-1.00E+00	-1.00E+00	0.00E+00
5.04E+00	2.10E-02	-1.00E+00	9.69E-01	9.99E-03	-1.00E+00	3.36E+00	0.00E+00	0.00E+00	-1.00E+00	-1.00E+00	0.00E+00
5.49E+00	1.71E-02	1.71E-02	9.73E-01	1.00E-02	7.68E-03	0.00E+00	0.00E+00	0.00E+00	1.25E-01	1.50E-01	0.00E+00
5.61E+00	1.71E-02	1.71E-02	9.73E-01	1.00E-02	7.69E-03	-1.05E-02	0.00E+00	0.00E+00	2.62E-02	1.50E-01	4.15E-01
5.76E+00	1.71E-02	1.71E-02	9.73E-01	1.00E-02	7.69E-03	-2.33E-02	0.00E+00	0.00E+00	2.63E-02	1.50E-01	4.15E-01
5.93E+00	1.71E-02	1.71E-02	9.73E-01	1.00E-02	7.69E-03	-3.89E-02	0.00E+00	0.00E+00	2.63E-02	1.50E-01	4.15E-01
6.15E+00	1.71E-02	1.71E-02	9.73E-01	1.00E-02	7.70E-03	-5.78E-02	0.00E+00	0.00E+00	2.63E-02	1.50E-01	4.15E-01
6.41E+00	1.70E-02	1.70E-02	9.73E-01	1.00E-02	7.70E-03	-8.08E-02	0.00E+00	0.00E+00	2.63E-02	1.50E-01	4.15E-01
6.73E+00	1.70E-02	1.70E-02	9.73E-01	1.00E-02	7.71E-03	-1.09E-01	0.00E+00	0.00E+00	2.64E-02	1.50E-01	4.15E-01
7.11E+00	1.70E-02	1.70E-02	9.73E-01	1.00E-02	7.71E-03	-1.43E-01	0.00E+00	0.00E+00	2.64E-02	1.50E-01	4.15E-01
7.58E+00	1.70E-02	1.70E-02	9.73E-01	1.00E-02	7.72E-03	-1.84E-01	0.00E+00	0.00E+00	2.65E-02	1.50E-01	4.15E-01
8.15E+00	1.69E-02	1.69E-02	9.73E-01	1.00E-02	7.74E-03	-2.34E-01	0.00E+00	0.00E+00	2.66E-02	1.50E-01	4.15E-01
8.85E+00	1.69E-02	1.69E-02	9.73E-01	1.00E-02	7.75E-03	-2.94E-01	0.00E+00	0.00E+00	2.68E-02	1.50E-01	4.15E-01
9.70E+00	1.68E-02	1.68E-02	9.73E-01	1.00E-02	7.77E-03	-3.67E-01	0.00E+00	0.00E+00	2.70E-02	1.50E-01	4.15E-01
1.07E+01	1.67E-02	1.67E-02	9.73E-01	1.00E-02	7.78E-03	-4.55E-01	0.00E+00	0.00E+00	2.73E-02	1.49E-01	4.15E-01
1.20E+01	1.67E-02	1.67E-02	9.73E-01	1.00E-02	7.81E-03	-5.62E-01	0.00E+00	0.00E+00	2.78E-02	1.49E-01	4.15E-01
1.35E+01	1.66E-02	1.66E-02	9.73E-01	1.00E-02	7.84E-03	-6.91E-01	0.00E+00	0.00E+00	2.86E-02	1.49E-01	4.15E-01
1.54E+01	1.64E-02	1.64E-02	9.74E-01	1.00E-02	7.87E-03	-8.45E-01	0.00E+00	0.00E+00	2.97E-02	1.49E-01	4.15E-01
1.76E+01	1.63E-02	1.63E-02	9.74E-01	1.00E-02	7.92E-03	-1.03E+00	0.00E+00	0.00E+00	3.16E-02	1.49E-01	4.15E-01
2.04E+01	1.61E-02	1.61E-02	9.74E-01	1.00E-02	7.97E-03	-1.25E+00	0.00E+00	0.00E+00	3.48E-02	1.49E-01	4.15E-01
2.37E+01	1.59E-02	1.59E-02	9 74E-01	1.00E-02	8.03E-03	-1.52E+00	0.00E+00	0.00E+00	4.09E-02	1.48E-01	4.15E-01

2.78E+01	1.56E-02	1.56E-02	9.74E-01	1.00E-02	8.11E-03	-1.83E+00	0.00E+00	0.00E+00	5.52E-02	1.48E-01	4.16E-01
3.27E+01	1.53E-02	1.53E-02	9.75E-01	1.01E-02	8.21E-03	-2.19E+00	0.00E+00	0.00E+00	1.21E-01	1.47E-01	4.16E-01
3.87E+01	1.49E-02	1.49E-02	9.75E-01	1.01E-02	8.32E-03	-1.47E+00	3.77E+00	0.00E+00	4.90E-02	1.44E-01	4.17E-01
4.61E+01	1.45E-02	1.45E-02	9.75E-01	1.01E-02	8.44E-03	-8.97E-01	3.94E+00	0.00E+00	6.16E-02	1.38E-01	4.16E-01
5.50E+01	1.40E-02	1.40E-02	9.76E-01	1.01E-02	8.59E-03	-5.40E-01	4.00E+00	0.00E+00	7.39E-02	1.31E-01	4.15E-01
6.58E+01	1.34E-02	1.34E-02	9.77E-01	1.01E-02	8.80E-03	-3.24E-01	3.95E+00	0.00E+00	8.46E-02	1.23E-01	4.14E-01
7.90E+01	1.25E-02	1.25E-02	9.77E-01	1.01E-02	9.08E-03	-1.94E-01	3.77E+00	0.00E+00	9.18E-02	1.16E-01	4.13E-01
9.51E+01	1.14E-02	1.14E-02	9.79E-01	1.01E-02	9.45E-03	-1.16E-01	3.49E+00	0.00E+00	9.45E-02	1.10E-01	4.13E-01
1.15E+02	1.01E-02	1.01E-02	9.80E-01	1.01E-02	9.89E-03	-7.01E-02	3.13E+00	0.00E+00	9.27E-02	1.04E-01	4.12E-01
1.38E+02	8.64E-03	8.64E-03	9.81E-01	1.01E-02	1.01E-02	-4.28E-02	2.72E+00	0.00E+00	9.01E-02	9.90E-02	4.12E-01
1.67E+02	7.22E-03	7.22E-03	9.83E-01	1.01E-02	1.01E-02	-2.65E-02	2.30E+00	0.00E+00	8.80E-02	9.45E-02	4.12E-01
2.03E+02	5.90E-03	5.90E-03	9.84E-01	1.01E-02	1.01E-02	-1.67E-02	1.90E+00	0.00E+00	8.56E-02	9.04E-02	4.12E-01
2.45E+02	4.73E-03	4.73E-03	9.85E-01	1.02E-02	1.02E-02	-1.07E-02	1.55E+00	0.00E+00	8.37E-02	8.67E-02	4.12E-01
2.97E+02	3.74E-03	3.74E-03	9.86E-01	1.02E-02	1.02E-02	-6.98E-03	1.25E+00	0.00E+00	8.24E-02	8.34E-02	4.12E-01
3.61E+02	2.92E-03	2.92E-03	9.87E-01	1.02E-02	1.02E-02	-4.66E-03	1.01E+00	0.00E+00	8.19E-02	8.07E-02	4.13E-01
4.38E+02	2.25E-03	2.25E-03	9.88E-01	1.02E-02	1.02E-02	-3.17E-03	8.14E-01	0.00E+00	8.19E-02	7.85E-02	4.13E-01
5.32E+02	1.73E-03	1.73E-03	9.88E-01	1.02E-02	1.02E-02	-2.20E-03	6.60E-01	0.00E+00	8.21E-02	7.66E-02	4.14E-01
6.46E+02	1.32E-03	1.32E-03	9.88E-01	1.02E-02	1.02E-02	-1.56E-03	5.39E-01	0.00E+00	8.27E-02	7.50E-02	4.14E-01
7.85E+02	1.01E-03	1.01E-03	9.89E-01	1.02E-02	1.02E-02	-1.13E-03	4.46E-01	0.00E+00	8.32E-02	7.37E-02	4.15E-01
9.54E+02	7.67E-04	7.67E-04	9.89E-01	1.02E-02	1.02E-02	-8.41E-04	3.74E-01	0.00E+00	8.37E-02	7.25E-02	4.16E-01
1.16E+03	5.83E-04	5.83E-04	9.89E-01	1.02E-02	1.02E-02	-6.37E-04	3.19E-01	0.00E+00	8.41E-02	7.13E-02	4.16E-01
1.41E+03	4.43E-04	4.43E-04	9.89E-01	1.02E-02	1.02E-02	-4.93E-04	2.77E-01	0.00E+00	8.44E-02	7.02E-02	4.17E-01
1.71E+03	3.36E-04	3.36E-04	9.89E-01	1.02E-02	1.02E-02	-3.88E-04	2.45E-01	0.00E+00	8.45E-02	6.89E-02	4.17E-01
2.09E+03	2.56E-04	2.56E-04	9.90E-01	1.02E-02	1.02E-02	-3.10E-04	2.20E-01	0.00E+00	8.44E-02	6.76E-02	4.18E-01
2.54E+03	1.94E-04	1.94E-04	9.90E-01	1.02E-02	1.02E-02	-2.50E-04	2.01E-01	0.00E+00	8.42E-02	6.61E-02	4.18E-01
3.09E+03	1.48E-04	1.48E-04	9.90E-01	1.02E-02	1.02E-02	-2.04E-04	1.85E-01	0.00E+00	8.37E-02	6.44E-02	4.19E-01
3.75E+03	1.12E-04	1.12E-04	9.90E-01	1.02E-02	1.02E-02	-1.67E-04	1.72E-01	0.00E+00	8.29E-02	6.25E-02	4.19E-01
4.57E+03	8.53E-05	8.53E-05	9.90E-01	1.02E-02	1.02E-02	-1.37E-04	1.61E-01	0.00E+00	8.20E-02	6.04E-02	4.18E-01
5.55E+03	6.48E-05	6.48E-05	9.90E-01	1.02E-02	1.02E-02	-1.13E-04	1.52E-01	0.00E+00	8.07E-02	5.81E-02	4.18E-01
6.76E+03	4.93E-05	4.93E-05	9.90E-01	1.02E-02	1.02E-02	-9.23E-05	1.44E-01	0.00E+00	7.91E-02	5.57E-02	4.17E-01
8.22E+03	3.75E-05	3.75E-05	9.90E-01	1.02E-02	1.02E-02	-7.53E-05	1.36E-01	0.00E+00	7.71E-02	5.31E-02	4.16E-01
1.00E+04	2.86E-05	2.86E-05	9.90E-01	1.02E-02	1.02E-02	-6.13E-05	1.29E-01	0.00E+00	7.47E-02	5.04E-02	4.15E-01

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time averaged (tav = 3600. 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)
1.00E+00	0.00E+00	1.90E-01	5.32E-02	2.00E-01	1.29E-01	0.00E+00	1.00E+00	0.00E+00	0.00E+00
1.45E+00	1.24E+00	3.41E-01	9.23E-01	7.42E+00	6.70E-01	1.89E-01	1.45E+00	4.49E-01	3.67E-03
1.90E+00	9.10E-01	4.92E-01	1.74E+00	1.01E+01	1.22E+00	3.78E-01	1.90E+00	8.98E-01	7.34E-03
2.35E+00	5.94E-01	6.43E-01	2.56E+00	1.20E+01	1.77E+00	5.67E-01	2.35E+00	1.35E+00	1.10E-02
2.80E+00	3.99E-01	7.94E-01	3.38E+00	1.34E+01	2.31E+00	7.56E-01	2.80E+00	1.80E+00	1.47E-02
3.25E+00	2.82E-01	9.44E-01	4.20E+00	1.45E+01	2.86E+00	9.45E-01	3.25E+00	2.25E+00	1.83E-02
3.70E+00	2.09E-01	1.10E+00	5.01E+00	1.54E+01	3.41E+00	1.13E+00	3.70E+00	2.70E+00	2.20E-02
4.14E+00	1.60E-01	1.25E+00	5.83E+00	1.60E+01	3.96E+00	1.32E+00	4.14E+00	3.14E+00	2.57E-02
4.59E+00	1.26E-01	1.40E+00	6.65E+00	1.64E+01	4.51E+00	1.51E+00	4.59E+00	3.59E+00	2.93E-02
5.04E+00	1.02E-01	1.55E+00	7.47E+00	1.67E+01	5.05E+00	1.70E+00	5.04E+00	4.04E+00	3.30E-02
5.49E+00	8.40E-02	1.70E+00	8.28E+00	1.68E+01	5.60E+00	1.89E+00	5.49E+00	4.49E+00	3.67E-02
5.61E+00	8.40E-02	1.70E+00	8.29E+00	1.68E+01	5.60E+00	1.94E+00	5.61E+00	4.61E+00	3.76E-02
5.76E+00	8.40E-02	1.70E+00	8.29E+00	1.68E+01	5.60E+00	2.00E+00	5.76E+00	4.76E+00	3.88E-02
5.93E+00	8.40E-02	1.70E+00	8.30E+00	1.68E+01	5.60E+00	2.08E+00	5.93E+00	4.93E+00	4.03E-02
6.15E+00	8.40E-02	1.70E+00	8.31E+00	1.67E+01	5.61E+00	2.17E+00	6.15E+00	5.15E+00	4.20E-02
6.41E+00	8.40E-02	1.70E+00	8.32E+00	1.67E+01	5.61E+00	2.28E+00	6.41E+00	5.41E+00	4.42E-02
6.73E+00	8.40E-02	1.70E+00	8.33E+00	1.67E+01	5.61E+00	2.41E+00	6.73E+00	5.72E+00	4.68E-02
7.11E+00	8.40E-02	1.70E+00	8.34E+00	1.67E+01	5.61E+00	2.57E+00	7.11E+00	6.11E+00	4.99E-02
7.58E+00	8.41E-02	1.70E+00	8.36E+00	1.67E+01	5.61E+00	2.77E+00	7.58E+00	6.58E+00	5.37E-02
8.15E+00	8.41E-02	1.70E+00	8.39E+00	1.67E+01	5.61E+00	3.01E+00	8.15E+00	7.15E+00	5.84E-02
8.85E+00	8.41E-02	1.70E+00	8.41E+00	1.66E+01	5.61E+00	3.30E+00	8.85E+00	7.85E+00	6.41E-02
9.70E+00	8.42E-02	1.70E+00	8.45E+00	1.66E+01	5.62E+00	3.66E+00	9.70E+00	8.70E+00	7.10E-02
1.07E+01	8.42E-02	1.70E+00	8.49E+00	1.65E+01	5.62E+00	4.09E+00	1.07E+01	9.73E+00	7.94E-02
1.20E+01	8.43E-02	1.70E+00	8.54E+00	1.64E+01	5.62E+00	4.62E+00	1.20E+01	1.10E+01	8.97E-02
1.35E+01	8.45E-02	1.70E+00	8.61E+00	1.62E+01	5.63E+00	5.26E+00	1.35E+01	1.25E+01	1.02E-01
1.54E+01	8.47E-02	1.70E+00	8.70E+00	1.59E+01	5.64E+00	6.05E+00	1.54E+01	1.44E+01	1.17E-01
1.76E+01	8.49E-02	1.70E+00	8.80E+00	1.54E+01	5.65E+00	7.00E+00	1.76E+01	1.66E+01	1.36E-01
2.04E+01	8.53E-02	1.70E+00	8.94E+00	1.48E+01	5.67E+00	8.16E+00	2.04E+01	1.94E+01	1.58E-01
2.37E+01	8.58E-02	1.70E+00	9.12E+00	1.38E+01	5.69E+00	9.57E+00	2.37E+01	2.27E+01	1.85E-01
2.78E+01	8.64E-02	1.70E+00	9.35E+00	1.23E+01	5.72E+00	1.13E+01	2.78E+01	2.68E+01	2.19E-01
3.27E+01	8.71E-02	1.70E+00	9.64E+00	1.02E+01	5.77E+00	1.34E+01	3.27E+01	3.17E+01	2.59E-01
3.87E+01	8.36E-02	2.12E+00	1.22E+01	7.84E+00	4.80E+00	1.59E+01	3.87E+01	3.77E+01	3.08E-01
4.61E+01	8.05E-02	2.75E+00	1.59E+01	6.05E+00	3.85E+00	1.91E+01	4.61E+01	4.51E+01	3.68E-01
5.50E+01	7.56E-02	3.55E+00	2.07E+01	4.70E+00	3.23E+00	2.29E+01	5.50E+01	5.40E+01	4.41E-01
6.58E+01	6.95E-02	4.53E+00	2.66E+01	3.69E+00	2.81E+00	2.77E+01	6.58E+01	6.48E+01	5.29E-01
7.90E+01	6.20E-02	5.70E+00	3.38E+01	2.93E+00	2.55E+00	3.37E+01	7.90E+01	7.80E+01	6.37E-01
9.51E+01	5.35E-02	7.05E+00	4.21E+01	2.38E+00	2.44E+00	4.12E+01	9.51E+01	9.41E+01	7.68E-01
1.15E+02	4.48E-02	8.54E+00	5.15E+01	1.96E+00	2.44E+00	5.04E+01	1.15E+02	1.14E+02	9.28E-01
1.38E+02	3.66E-02	1.01E+01	6.18E+01	1.65E+00	2.54E+00	6.16E+01	1.38E+02	1.37E+02	1.12E+00
1.67E+02	2.92E-02	1.18E+01	7.27E+01	1.42E+00	2.76E+00	7.53E+01	1.67E+02	1.66E+02	1.36E+00
2.03E+02	2.29E-02	1.34E+01	8.40E+01	1.25E+00	3.11E+00	9.21E+01	2.03E+02	2.02E+02	1.65E+00
2.45E+02	1.79E-02	1.51E+01	9.56E+01	1.11E+00	3.59E+00	1.12E+02	2.45E+02	2.44E+02	2.00E+00
2.97E+02	1.38E-02	1.67E+01	1.07E+02	1.00E+00	4.21E+00	1.37E+02	2.97E+02	2.96E+02	2.42E+00
3.61E+02	1.07E-02	1.83E+01	1.20E+02	9.17E-01	5.01E+00	1.67E+02	3.61E+02	3.60E+02	2.94E+00
4.38E+02	8.26E-03	1.98E+01	1.32E+02	8.48E-01	6.01E+00	2.03E+02	4.38E+02	4.37E+02	3.57E+00

5.32E+02	6.39E-03	2.12E+01	1.45E+02	7.90E-01	7.26E+00
6.46E+02	4.96E-03	2.26E+01	1.59E+02	7.42E-01	8.78E+00
7.85E+02	3.87E-03	2.39E+01	1.74E+02	7.00E-01	1.07E+01
9.54E+02	3.03E-03	2.53E+01	1.91E+02	6.64E-01	1.29E+01
1.16E+03	2.39E-03	2.66E+01	2.10E+02	6.31E-01	1.57E+01
1.41E+03	1.90E-03	2.79E+01	2.32E+02	6.01E-01	1.90E+01
1.71E+03	1.52E-03	2.92E+01	2.57E+02	5.73E-01	2.29E+01
2.09E+03	1.22E-03	3.06E+01	2.86E+02	5.47E-01	2.76E+01
2.54E+03	9.90E-04	3.21E+01	3.20E+02	5.22E-01	3.32E+01
3.09E+03	8.04E-04	3.37E+01	3.60E+02	4.98E-01	3.98E+01
3.75E+03	6.55E-04	3.54E+01	4.05E+02	4.74E-01	4.75E+01
4.57E+03	5.35E-04	3.72E+01	4.59E+02	4.51E-01	5.65E+01
5.55E+03	4.37E-04	3.91E+01	5.20E+02	4.28E-01	6.71E+01
6.76E+03	3.57E-04	4.13E+01	5.90E+02	4.06E-01	7.94E+01
8.22E+03	2.92E-04	4.36E+01	6.70E+02	3.84E-01	9.35E+01
1.00E+04	2.38E-04	4.62E+01	7.60E+02	3.63E-01	1.10E+02

2.47E+02	5.32E+02	5.31E+02	4.34E+00
3.00E+02	6.46E+02	6.45E+02	5.27E+00
3.62E+02	7.85E+02	7.84E+02	6.40E+00
4.37E+02	9.54E+02	9.53E+02	7.78E+00
5.27E+02	1.16E+03	1.16E+03	9.47E+00
6.34E+02	1.41E+03	1.41E+03	1.15E+01
7.61E+02	1.71E+03	1.71E+03	1.40E+01
9.12E+02	2.09E+03	2.08E+03	1.70E+01
1.09E+03	2.54E+03	2.54E+03	2.07E+01
1.31E+03	3.09E+03	3.08E+03	2.52E+01
1.57E+03	3.75E+03	3.75E+03	3.06E+01
1.87E+03	4.57E+03	4.56E+03	3.73E+01
2.24E+03	5.55E+03	5.55E+03	4.53E+01
2.68E+03	6.76E+03	6.75E+03	5.52E+01
3.20E+03	8.22E+03	8.22E+03	6.71E+01
3.83E+03	1.00E+04	1.00E+04	8.16E+01

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time averaged (tav = 3600. s) volume concentration: concentration in the z = .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	8.10E+03	1.62E+04	2.12E-01	8.72E-01	8.23E-01	3.01E-01	7.47E-03	5.41E-06	0.00E+00
1.45E+00	8.10E+03	1.62E+04	1.64E+00	7.43E-27	5.11E-27	1.66E-27	2.54E-28	1.83E-29	6.17E-31
1.90E+00	8.10E+03	1.62E+04	3.06E+00	1.55E-15	1.06E-15	3.45E-16	5.29E-17	3.82E-18	1.30E-19
2.35E+00	8.10E+03	1.62E+04	4.48E+00	8.22E-11	5.65E-11	1.83E-11	2.81E-12	2.03E-13	6.95E-15
2.80E+00	8.10E+03	1.62E+04	5.91E+00	2.80E-08	1.92E-08	6.25E-09	9.58E-10	6.93E-11	2.37E-12
3.25E+00	8.10E+03	1.62E+04	7.33E+00	1.01E-06	6.95E-07	2.25E-07	3.46E-08	2.50E-09	8.54E-11
3.70E+00	8.10E+03	1.62E+04	8.75E+00	1.12E-05	7.69E-06	2.50E-06	3.83E-07	2.77E-08	9.47E-10
4.14E+00	8.10E+03	1.62E+04	1.02E+01	6.18E-05	4.25E-05	1.38E-05	2.12E-06	1.53E-07	5.24E-09
4.59E+00	8.10E+03	1.62E+04	1.16E+01	2.20E-04	1.51E-04	4.91E-05	7.52E-06	5.45E-07	1.86E-08
5.04E+00	8.10E+03	1.62E+04	1.30E+01	5.81E-04	3.99E-04	1.30E-04	1.99E-05	1.44E-06	4.93E-08
5.49E+00	8.10E+03	1.62E+04	1.44E+01	1.25E-03	8.57E-04	2.78E-04	4.27E-05	3.09E-06	1.05E-07
5.61E+00	8.10E+03	1.62E+04	1.45E+01	1.25E-03	8.57E-04	2.78E-04	4.27E-05	3.09E-06	1.06E-07
5.76E+00	8.10E+03	1.62E+04	1.45E+01	1.25E-03	8.58E-04	2.78E-04	4.27E-05	3.09E-06	1.06E-07
5.93E+00	8.10E+03	1.62E+04	1.45E+01	1.25E-03	8.58E-04	2.79E-04	4.27E-05	3.09E-06	1.06E-07
6.15E+00	8.10E+03	1.62E+04	1.45E+01	1.25E-03	8.59E-04	2.79E-04	4.28E-05	3.10E-06	1.06E-07
6.41E+00	8.10E+03	1.62E+04	1.45E+01	1.25E-03	8.61E-04	2.79E-04	4.29E-05	3.10E-06	1.06E-07
6.73E+00	8.10E+03	1.62E+04	1.45E+01	1.26E-03	8.64E-04	2.80E-04	4.30E-05	3.11E-06	1.06E-07
7.11E+00	8.10E+03	1.62E+04	1.46E+01	1.26E-03	8.68E-04	2.82E-04	4.32E-05	3.13E-06	1.07E-07
7.58E+00	8.10E+03	1.62E+04	1.46E+01	1.27E-03	8.76E-04	2.84E-04	4.36E-05	3.16E-06	1.08E-07
8.15E+00	8.10E+03	1.62E+04	1.46E+01	1.29E-03	8.88E-04	2.88E-04	4.42E-05	3.20E-06	1.09E-07
8.85E+00	8.10E+03	1.62E+04	1.47E+01	1.32E-03	9.06E-04	2.94E-04	4.51E-05	3.27E-06	1.12E-07
9.70E+00	8.10E+03	1.62E+04	1.47E+01	1.36E-03	9.35E-04	3.03E-04	4.65E-05	3.37E-06	1.15E-07
1.07E+01	8.10E+03	1.62E+04	1.48E+01	1.43E-03	9.80E-04	3.18E-04	4.88E-05	3.53E-06	1.21E-07
1.20E+01	8.10E+03	1.62E+04	1.49E+01	1.53E-03	1.05E-03	3.41E-04	5.23E-05	3.79E-06	1.30E-07
1.35E+01	8.10E+03	1.62E+04	1.50E+01	1.70E-03	1.17E-03	3.79E-04	5.81E-05	4.20E-06	1.44E-07
1.54E+01	8.10E+03	1.62E+04	1.52E+01	1.98E-03	1.36E-03	4.41E-04	6.77E-05	4.90E-06	1.67E-07
1.76E+01	8.10E+03	1.62E+04	1.53E+01	2.47E-03	1.69E-03	5.50E-04	8.44E-05	6.11E-06	2.09E-07
2.04E+01	8.10E+03	1.62E+04	1.56E+01	3.38E-03	2.32E-03	7.53E-04	1.16E-04	8.36E-06	2.86E-07
2.37E+01	8.10E+03	1.62E+04	1.59E+01	5.22E-03	3.59E-03	1.16E-03	1.79E-04	1.29E-05	4.42E-07
2.78E+01	8.11E+03	1.62E+04	1.63E+01	9.32E-03	6.40E-03	2.08E-03	3.19E-04	2.31E-05	7.89E-07
3.27E+01	8.11E+03	1.62E+04	1.68E+01	1.92E-02	1.32E-02	4.28E-03	6.56E-04	4.75E-05	1.62E-06
3.87E+01	8.11E+03	1.62E+04	2.12E+01	2.32E-02	1.59E-02	5.17E-03	7.93E-04	5.74E-05	1.96E-06
4.61E+01	8.11E+03	1.62E+04	2.77E+01	2.47E-02	1.70E-02	5.51E-03	8.45E-04	6.12E-05	2.09E-06
5.50E+01	8.11E+03	1.62E+04	3.60E+01	2.78E-02	1.91E-02	6.19E-03	9.50E-04	6.88E-05	2.35E-06
6.58E+01	8.11E+03	1.62E+04	4.63E+01	3.09E-02	2.13E-02	6.90E-03	1.06E-03	7.66E-05	2.62E-06
7.90E+01	8.11E+03	1.62E+04	5.88E+01	3.35E-02	2.30E-02	7.48E-03	1.15E-03	8.31E-05	2.84E-06
9.51E+01	8.12E+03	1.62E+04	7.33E+01	3.45E-02	2.37E-02	7.70E-03	1.18E-03	8.56E-05	2.93E-06
1.15E+02	8.12E+03	1.62E+04	8.96E+01	3.33E-02	2.29E-02	7.43E-03	1.14E-03	8.25E-05	2.82E-06
1.38E+02	8.13E+03	1.62E+04	1.07E+02	3.01E-02	2.07E-02	6.72E-03	1.03E-03	7.46E-05	2.55E-06
1.67E+02	8.13E+03	1.62E+04	1.26E+02	2.57E-02	1.77E-02	5.73E-03	8.79E-04	6.36E-05	2.17E-06
2.03E+02	8.14E+03	1.62E+04	1.46E+02	2.09E-02	1.44E-02	4.67E-03	7.17E-04	5.19E-05	1.78E-06
2.45E+02	8.15E+03	1.62E+04	1.66E+02	1.66E-02	1.14E-02	3.69E-03	5.67E-04	4.10E-05	1.40E-06
2.97E+02	8.16E+03	1.62E+04	1.87E+02	1.28E-02	8.80E-03	2.86E-03	4.38E-04	3.17E-05	1.09E-06
3.61E+02	8.17E+03	1.62E+04	2.08E+02	9.77E-03	6.72E-03	2.18E-03	3.34E-04	2.42E-05	8.28E-07
4.38E+02	8.18E+03	1.62E+04	2.30E+02	7.38E-03	5.07E-03	1.65E-03	2.52E-04	1.83E-05	6.25E-07
5.32E+02	8.20E+03	1.62E+04	2.53E+02	5.53E-03	3.80E-03	1.23E-03	1.89E-04	1.37E-05	4.69E-07
6.46E+02	8.22E+03	1.62E+04	2.77E+02	4.12E-03	2.83E-03	9.19E-04	1.41E-04	1.02E-05	3.48E-07
7.85E+02	8.25E+03	1.62E+04	3.03E+02	3.06E-03	2.10E-03	6.82E-04	1.05E-04	7.58E-06	2.59E-07
9.54E+02	8.28E+03	1.62E+04	3.32E+02	2.26E-03	1.55E-03	5.04E-04	7.73E-05	5.60E-06	1.92E-07
1.16E+03	8.32E+03	1.62E+04	3.65E+02	1.66E-03	1.14E-03	3.71E-04	5.70E-05	4.13E-06	1.42E-07
1.41E+03	8.37E+03	1.62E+04	4.03E+02	1.22E-03	8.40E-04	2.73E-04	4.18E-05	3.03E-06	1.04E-07
1.71E+03	8.43E+03	1.62E+04	4.46E+02	8.95E-04	6.15E-04	2.00E-04	3.06E-05	2.22E-06	7.60E-08
2.09E+03	8.50E+03	1.62E+04	4.96E+02	6.54E-04	4.50E-04	1.46E-04	2.24E-05	1.62E-06	5.56E-08
2.54E+03	8.59E+03	1.62E+04	5.55E+02	4.77E-04	3.28E-04	1.06E-04	1.63E-05	1.18E-06	4.04E-08
3.09E+03	8.69E+03	1.62E+04	6.24E+02	3.47E-04	2.39E-04	7.75E-05	1.19E-05	8.61E-07	2.94E-08
3.75E+03	8.82E+03	1.62E+04	7.03E+02	2.53E-04	1.74E-04	5.65E-05	8.66E-06	6.27E-07	2.15E-08
4.57E+03	8.97E+03	1.62E+04	7.95E+02	1.84E-04	1.27E-04	4.12E-05	6.31E-06	4.57E-07	1.57E-08
5.55E+03	9.16E+03	1.62E+04	9.01E+02	1.35E-04	9.26E-05	3.00E-05	4.61E-06	3.34E-07	1.14E-08
6.76E+03	9.39E+03	1.62E+04	1.02E+03	9.86E-05	6.78E-05	2.20E-05	3.37E-06	2.44E-07	8.32E-09
8.22E+03	9.67E+03	1.62E+04	1.16E+03	7.24E-05	4.98E-05	1.62E-05	2.48E-06	1.79E-07	6.15E-09
1.00E+04	1.00E+04	1.62E+04	1.32E+03	5.34E-05	3.67E-05	1.19E-05	1.83E-06	1.32E-07	4.54E-09

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time averaged (tav = 3600. 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	8.10E+03	1.62E+04	2.12E-01	6.10E-09	5.76E-09	2.11E-09	5.22E-11	3.78E-14	0.00E+00
1.45E+00	8.10E+03	1.62E+04	1.64E+00	1.80E-20	1.24E-20	4.03E-21	6.17E-22	4.44E-23	1.50E-24
1.90E+00	8.10E+03	1.62E+04	3.06E+00	5.09E-13	3.50E-13	1.14E-13	1.74E-14	1.26E-15	4.28E-17
2.35E+00	8.10E+03	1.62E+04	4.48E+00	1.65E-09	1.13E-09	3.69E-10	5.65E-11	4.09E-12	1.40E-13
2.80E+00	8.10E+03	1.62E+04	5.91E+00	1.58E-07	1.08E-07	3.52E-08	5.40E-09	3.91E-10	1.34E-11
3.25E+00	8.10E+03	1.62E+04	7.33E+00	2.88E-06	1.98E-06	6.43E-07	9.86E-08	7.14E-09	2.44E-10
3.70E+00	8.10E+03	1.62E+04	8.75E+00	2.15E-05	1.48E-05	4.80E-06	7.36E-07	5.33E-08	1.82E-09

4.14E+00	8.10E+03	1.62E+04	1.02E+01	9.39E-05	6.45E-05	2.09E-05	3.21E-06	2.32E-07	7.95E-09
4.59E+00	8.10E+03	1.62E+04	1.16E+01	2.88E-04	1.98E-04	6.44E-05	9.87E-06	7.15E-07	2.44E-08
5.04E+00	8.10E+03	1.62E+04	1.30E+01	6.95E-04	4.78E-04	1.55E-04	2.38E-05	1.72E-06	5.89E-08
5.49E+00	8.10E+03	1.62E+04	1.44E+01	1.41E-03	9.67E-04	3.14E-04	4.81E-05	3.48E-06	1.19E-07
5.61E+00	8.10E+03	1.62E+04	1.45E+01	1.41E-03	9.67E-04	3.14E-04	4.81E-05	3.48E-06	1.19E-07
5.76E+00	8.10E+03	1.62E+04	1.45E+01	1.41E-03	9.67E-04	3.14E-04	4.81E-05	3.48E-06	1.19E-07
5.93E+00	8.10E+03	1.62E+04	1.45E+01	1.41E-03	9.68E-04	3.14E-04	4.82E-05	3.49E-06	1.19E-07
6.15E+00	8.10E+03	1.62E+04	1.45E+01	1.41E-03	9.69E-04	3.14E-04	4.82E-05	3.49E-06	1.19E-07
6.41E+00	8.10E+03	1.62E+04	1.45E+01	1.41E-03	9.70E-04	3.15E-04	4.83E-05	3.50E-06	1.20E-07
6.73E+00	8.10E+03	1.62E+04	1.45E+01	1.42E-03	9.73E-04	3.16E-04	4.85E-05	3.51E-06	1.20E-07
7.11E+00	8.10E+03	1.62E+04	1.46E+01	1.42E-03	9.78E-04	3.18E-04	4.87E-05	3.53E-06	1.20E-07
7.58E+00	8.10E+03	1.62E+04	1.46E+01	1.44E-03	9.87E-04	3.20E-04	4.91E-05	3.56E-06	1.21E-07
8.15E+00	8.10E+03	1.62E+04	1.46E+01	1.45E-03	9.99E-04	3.24E-04	4.97E-05	3.60E-06	1.23E-07
8.85E+00	8.10E+03	1.62E+04	1.47E+01	1.48E-03	1.02E-03	3.31E-04	5.07E-05	3.67E-06	1.26E-07
9.70E+00	8.10E+03	1.62E+04	1.47E+01	1.53E-03	1.05E-03	3.41E-04	5.23E-05	3.79E-06	1.29E-07
1.07E+01	8.10E+03	1.62E+04	1.48E+01	1.60E-03	1.10E-03	3.57E-04	5.47E-05	3.96E-06	1.35E-07
1.20E+01	8.10E+03	1.62E+04	1.49E+01	1.71E-03	1.18E-03	3.82E-04	5.86E-05	4.24E-06	1.45E-07
1.35E+01	8.10E+03	1.62E+04	1.50E+01	1.89E-03	1.30E-03	4.22E-04	6.48E-05	4.69E-06	1.60E-07
1.54E+01	8.10E+03	1.62E+04	1.52E+01	2.19E-03	1.51E-03	4.89E-04	7.51E-05	5.43E-06	1.86E-07
1.76E+01	8.10E+03	1.62E+04	1.53E+01	2.72E-03	1.87E-03	6.06E-04	9.29E-05	6.73E-06	2.30E-07
2.04E+01	8.10E+03	1.62E+04	1.56E+01	3.68E-03	2.53E-03	8.21E-04	1.26E-04	9.12E-06	3.11E-07
2.37E+01	8.10E+03	1.62E+04	1.59E+01	5.61E-03	3.86E-03	1.25E-03	1.92E-04	1.39E-05	4.75E-07
2.78E+01	8.11E+03	1.62E+04	1.63E+01	9.84E-03	6.76E-03	2.19E-03	3.37E-04	2.44E-05	8.33E-07
3.27E+01	8.11E+03	1.62E+04	1.68E+01	1.98E-02	1.36E-02	4.42E-03	6.77E-04	4.90E-05	1.67E-06
3.87E+01	8.11E+03	1.62E+04	2.12E+01	2.40E-02	1.65E-02	5.36E-03	8.21E-04	5.95E-05	2.03E-06
4.61E+01	8.11E+03	1.62E+04	2.77E+01	2.59E-02	1.78E-02	5.78E-03	8.86E-04	6.42E-05	2.20E-06
5.50E+01	8.11E+03	1.62E+04	3.60E+01	2.92E-02	2.00E-02	6.51E-03	9.98E-04	7.23E-05	2.47E-06
6.58E+01	8.11E+03	1.62E+04	4.63E+01	3.22E-02	2.22E-02	7.19E-03	1.10E-03	7.99E-05	2.73E-06
7.90E+01	8.11E+03	1.62E+04	5.88E+01	3.42E-02	2.35E-02	7.64E-03	1.17E-03	8.48E-05	2.90E-06
9.51E+01	8.12E+03	1.62E+04	7.33E+01	3.43E-02	2.36E-02	7.66E-03	1.17E-03	8.50E-05	2.91E-06
1.15E+02	8.12E+03	1.62E+04	8.96E+01	3.23E-02	2.22E-02	7.21E-03	1.11E-03	8.00E-05	2.73E-06
1.38E+02	8.13E+03	1.62E+04	1.07E+02	2.88E-02	1.98E-02	6.42E-03	9.85E-04	7.13E-05	2.44E-06
1.67E+02	8.13E+03	1.62E+04	1.26E+02	2.45E-02	1.68E-02	5.46E-03	8.37E-04	6.06E-05	2.07E-06
2.03E+02	8.14E+03	1.62E+04	1.46E+02	2.01E-02	1.38E-02	4.48E-03	6.86E-04	4.97E-05	1.70E-06
2.45E+02	8.15E+03	1.62E+04	1.66E+02	1.60E-02	1.10E-02	3.57E-03	5.47E-04	3.96E-05	1.35E-06
2.97E+02	8.16E+03	1.62E+04	1.87E+02	1.25E-02	8.57E-03	2.78E-03	4.27E-04	3.09E-05	1.06E-06
3.61E+02	8.17E+03	1.62E+04	2.08E+02	9.58E-03	6.59E-03	2.14E-03	3.28E-04	2.38E-05	8.12E-07
4.38E+02	8.18E+03	1.62E+04	2.30E+02	7.28E-03	5.00E-03	1.62E-03	2.49E-04	1.80E-05	6.17E-07
5.32E+02	8.20E+03	1.62E+04	2.53E+02	5.48E-03	3.76E-03	1.22E-03	1.87E-04	1.36E-05	4.64E-07
6.46E+02	8.22E+03	1.62E+04	2.77E+02	4.09E-03	2.81E-03	9.14E-04	1.40E-04	1.01E-05	3.46E-07
7.85E+02	8.25E+03	1.62E+04	3.03E+02	3.04E-03	2.09E-03	6.79E-04	1.04E-04	7.54E-06	2.58E-07
9.54E+02	8.28E+03	1.62E+04	3.32E+02	2.25E-03	1.55E-03	5.03E-04	7.71E-05	5.58E-06	1.91E-07
1.16E+03	8.32E+03	1.62E+04	3.65E+02	1.66E-03	1.14E-03	3.71E-04	5.68E-05	4.12E-06	1.41E-07
1.41E+03	8.37E+03	1.62E+04	4.03E+02	1.22E-03	8.39E-04	2.72E-04	4.18E-05	3.03E-06	1.03E-07
1.71E+03	8.43E+03	1.62E+04	4.46E+02	8.94E-04	6.15E-04	2.00E-04	3.06E-05	2.22E-06	7.59E-08
2.09E+03	8.50E+03	1.62E+04	4.96E+02	6.54E-04	4.49E-04	1.46E-04	2.24E-05	1.62E-06	5.55E-08
2.54E+03	8.59E+03	1.62E+04	5.55E+02	4.77E-04	3.28E-04	1.06E-04	1.63E-05	1.18E-06	4.04E-08
3.09E+03	8.69E+03	1.62E+04	6.24E+02	3.47E-04	2.39E-04	7.75E-05	1.19E-05	8.61E-07	2.94E-08
3.75E+03	8.82E+03	1.62E+04	7.03E+02	2.53E-04	1.74E-04	5.65E-05	8.66E-06	6.27E-07	2.15E-08
4.57E+03	8.97E+03	1.62E+04	7.95E+02	1.84E-04	1.27E-04	4.12E-05	6.31E-06	4.57E-07	1.57E-08
5.55E+03	9.16E+03	1.62E+04	9.01E+02	1.35E-04	9.25E-05	3.00E-05	4.61E-06	3.34E-07	1.14E-08
6.76E+03	9.39E+03	1.62E+04	1.02E+03	9.86E-05	6.77E-05	2.20E-05	3.37E-06	2.44E-07	8.32E-09
8.22E+03	9.67E+03	1.62E+04	1.16E+03	7.24E-05	4.98E-05	1.62E-05	2.48E-06	1.79E-07	6.15E-09
1.00E+04	1.00E+04	1.62E+04	1.32E+03	5.34E-05	3.67E-05	1.19E-05	1.83E-06	1.32E-07	4.54E-09

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time averaged (tav = 3600. s) volume concentration: concentration in the z = 2.00 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	8.10E+03	1.62E+04	2.12E-01	5.65E-43	5.34E-43	1.95E-43	4.20E-45	0.00E+00	0.00E+00
1.45E+00	8.10E+03	1.62E+04	1.64E+00	9.45E-15	6.50E-15	2.11E-15	3.23E-16	2.33E-17	7.84E-19
1.90E+00	8.10E+03	1.62E+04	3.06E+00	1.71E-10	1.17E-10	3.81E-11	5.84E-12	4.22E-13	1.44E-14
2.35E+00	8.10E+03	1.62E+04	4.48E+00	4.81E-08	3.31E-08	1.07E-08	1.65E-09	1.19E-10	4.07E-12
2.80E+00	8.10E+03	1.62E+04	5.91E+00	1.46E-06	1.00E-06	3.25E-07	4.99E-08	3.61E-09	1.23E-10
3.25E+00	8.10E+03	1.62E+04	7.33E+00	1.38E-05	9.46E-06	3.07E-06	4.71E-07	3.41E-08	1.16E-09
3.70E+00	8.10E+03	1.62E+04	8.75E+00	6.65E-05	4.57E-05	1.48E-05	2.28E-06	1.65E-07	5.63E-09
4.14E+00	8.10E+03	1.62E+04	1.02E+01	2.13E-04	1.46E-04	4.75E-05	7.29E-06	5.27E-07	1.80E-08
4.59E+00	8.10E+03	1.62E+04	1.16E+01	5.22E-04	3.58E-04	1.16E-04	1.78E-05	1.29E-06	4.41E-08
5.04E+00	8.10E+03	1.62E+04	1.30E+01	1.06E-03	7.31E-04	2.37E-04	3.64E-05	2.63E-06	9.01E-08
5.49E+00	8.10E+03	1.62E+04	1.44E+01	1.90E-03	1.31E-03	4.25E-04	6.51E-05	4.71E-06	1.61E-07
5.61E+00	8.10E+03	1.62E+04	1.45E+01	1.90E-03	1.31E-03	4.25E-04	6.51E-05	4.71E-06	1.61E-07
5.76E+00	8.10E+03	1.62E+04	1.45E+01	1.90E-03	1.31E-03	4.25E-04	6.51E-05	4.71E-06	1.61E-07
5.93E+00	8.10E+03	1.62E+04	1.45E+01	1.90E-03	1.31E-03	4.25E-04	6.51E-05	4.71E-06	1.61E-07
6.15E+00	8.10E+03	1.62E+04	1.45E+01	1.91E-03	1.31E-03	4.25E-04	6.52E-05	4.72E-06	1.61E-07
6.41E+00	8.10E+03	1.62E+04	1.45E+01	1.91E-03	1.31E-03	4.26E-04	6.53E-05	4.73E-06	1.62E-07
6.73E+00	8.10E+03	1.62E+04	1.45E+01	1.91E-03	1.32E-03	4.27E-04	6.55E-05	4.74E-06	1.62E-07
7.11E+00	8.10E+03	1.62E+04	1.46E+01	1.92E-03	1.32E-03	4.29E-04	6.58E-05	4.76E-06	1.63E-07
7.58E+00	8.10E+03	1.62E+04	1.46E+01	1.94E-03	1.33E-03	4.32E-04	6.63E-05	4.80E-06	1.64E-07
8.15E+00	8.10E+03	1.62E+04	1.46E+01	1.96E-03	1.35E-03	4.37E-04	6.70E-05	4.85E-06	1.66E-07
8.85E+00	8.10E+03	1.62E+04	1.47E+01	1.99E-03	1.37E-03	4.45E-04	6.82E-05	4.94E-06	1.69E-07
9.70E+00	8.10E+03	1.62E+04	1.47E+01	2.05E-03	1.41E-03	4.58E-04	7.02E-05	5.08E-06	1.73E-07
1.07E+01	8.10E+03	1.62E+04	1.48E+01	2.14E-03	1.47E-03	4.77E-04	7.31E-05	5.30E-06	1.81E-07
1.20E+01	8.10E+03	1.62E+04	1.49E+01	2.28E-03	1.56E-03	5.08E-04	7.78E-05	5.64E-06	1.93E-07
1.35E+01	8.10E+03	1.62E+04	1.50E+01	2.50E-03	1.72E-03	5.57E-04	8.54E-05	6.18E-06	2.11E-07
1.54E+01	8.10E+03	1.62E+04	1.52E+01	2.86E-03	1.97E-03	6.38E-04	9.79E-05	7.09E-06	2.42E-07
1.76E+01	8.10E+03	1.62E+04	1.53E+01	3.48E-03	2.39E-03	7.77E-04	1.19E-04	8.63E-06	2.95E-07
2.04E+01	8.10E+03	1.62E+04	1.56E+01	4.61E-03	3.17E-03	1.03E-03	1.58E-04	1.14E-05	3.90E-07
2.37E+01	8.10E+03	1.62E+04	1.59E+01	6.80E-03	4.67E-03	1.52E-03	2.33E-04	1.68E-05	5.75E-07
2.78E+01	8.11E+03	1.62E+04	1.63E+01	1.14E-02	7.82E-03	2.54E-03	3.89E-04	2.82E-05	9.64E-07
3.27E+01	8.11E+03	1.62E+04	1.68E+01	2.16E-02	1.48E-02	4.81E-03	7.38E-04	5.35E-05	1.82E-06
3.87E+01	8.11E+03	1.62E+04	2.12E+01	2.64E-02	1.81E-02	5.88E-03	9.02E-04	6.53E-05	2.23E-06
4.61E+01	8.11E+03	1.62E+04	2.77E+01	2.92E-02	2.01E-02	6.51E-03	9.99E-04	7.23E-05	2.47E-06
5.50E+01	8.11E+03	1.62E+04	3.60E+01	3.28E-02	2.26E-02	7.32E-03	1.12E-03	8.13E-05	2.78E-06
6.58E+01	8.11E+03	1.62E+04	4.63E+01	3.52E-02	2.42E-02	7.86E-03	1.21E-03	8.73E-05	2.99E-06
7.90E+01	8.11E+03	1.62E+04	5.88E+01	3.53E-02	2.43E-02	7.88E-03	1.21E-03	8.75E-05	2.99E-06
9.51E+01	8.12E+03	1.62E+04	7.33E+01	3.30E-02	2.27E-02	7.36E-03	1.13E-03	8.17E-05	2.79E-06
1.15E+02	8.12E+03	1.62E+04	8.96E+01	2.92E-02	2.00E-02	6.51E-03	9.98E-04	7.23E-05	2.47E-06

1.38E+02	8.13E+03	1.62E+04	1.07E+02	2.50E-02	1.72E-02	5.59E-03	8.57E-04	6.21E-05	2.12E-06
1.67E+02	8.13E+03	1.62E+04	1.26E+02	2.11E-02	1.45E-02	4.72E-03	7.24E-04	5.24E-05	1.79E-06
2.03E+02	8.14E+03	1.62E+04	1.46E+02	1.76E-02	1.21E-02	3.93E-03	6.02E-04	4.36E-05	1.49E-06
2.45E+02	8.15E+03	1.62E+04	1.66E+02	1.44E-02	9.89E-03	3.21E-03	4.92E-04	3.56E-05	1.22E-06
2.97E+02	8.16E+03	1.62E+04	1.87E+02	1.15E-02	7.92E-03	2.57E-03	3.94E-04	2.85E-05	9.78E-07
3.61E+02	8.17E+03	1.62E+04	2.08E+02	9.05E-03	6.22E-03	2.02E-03	3.10E-04	2.24E-05	7.66E-07
4.38E+02	8.18E+03	1.62E+04	2.30E+02	6.99E-03	4.80E-03	1.56E-03	2.39E-04	1.73E-05	5.92E-07
5.32E+02	8.20E+03	1.62E+04	2.53E+02	5.32E-03	3.66E-03	1.19E-03	1.82E-04	1.32E-05	4.51E-07
6.46E+02	8.22E+03	1.62E+04	2.77E+02	4.02E-03	2.76E-03	8.96E-04	1.37E-04	9.95E-06	3.40E-07
7.85E+02	8.25E+03	1.62E+04	3.03E+02	3.00E-03	2.06E-03	6.70E-04	1.03E-04	7.45E-06	2.54E-07
9.54E+02	8.28E+03	1.62E+04	3.32E+02	2.23E-03	1.53E-03	4.98E-04	7.64E-05	5.53E-06	1.89E-07
1.16E+03	8.32E+03	1.62E+04	3.65E+02	1.65E-03	1.13E-03	3.68E-04	5.65E-05	4.09E-06	1.40E-07
1.41E+03	8.37E+03	1.62E+04	4.03E+02	1.22E-03	8.36E-04	2.71E-04	4.16E-05	3.01E-06	1.03E-07
1.71E+03	8.43E+03	1.62E+04	4.46E+02	8.92E-04	6.13E-04	1.99E-04	3.05E-05	2.21E-06	7.57E-08
2.09E+03	8.50E+03	1.62E+04	4.96E+02	6.52E-04	4.48E-04	1.46E-04	2.23E-05	1.62E-06	5.54E-08
2.54E+03	8.59E+03	1.62E+04	5.55E+02	4.76E-04	3.27E-04	1.06E-04	1.63E-05	1.18E-06	4.03E-08
3.09E+03	8.69E+03	1.62E+04	6.24E+02	3.47E-04	2.39E-04	7.74E-05	1.19E-05	8.60E-07	2.94E-08
3.75E+03	8.82E+03	1.62E+04	7.03E+02	2.53E-04	1.74E-04	5.64E-05	8.65E-06	6.27E-07	2.15E-08
4.57E+03	8.97E+03	1.62E+04	7.95E+02	1.84E-04	1.27E-04	4.11E-05	6.31E-06	4.57E-07	1.56E-08
5.55E+03	9.16E+03	1.62E+04	9.01E+02	1.35E-04	9.25E-05	3.00E-05	4.61E-06	3.34E-07	1.14E-08
6.76E+03	9.39E+03	1.62E+04	1.02E+03	9.85E-05	6.77E-05	2.20E-05	3.37E-06	2.44E-07	8.31E-09
8.22E+03	9.67E+03	1.62E+04	1.16E+03	7.24E-05	4.98E-05	1.62E-05	2.48E-06	1.79E-07	6.15E-09
1.00E+04	1.00E+04	1.62E+04	1.32E+03	5.34E-05	3.67E-05	1.19E-05	1.83E-06	1.32E-07	4.54E-09

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time averaged (tav = 3600. s) volume concentration: concentration in the z = 4.00 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	8.10E+03	1.62E+04	2.12E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
1.45E+00	8.10E+03	1.62E+04	1.64E+00	3.26E-06	2.24E-06	7.29E-07	1.12E-07	8.03E-09	2.71E-10
1.90E+00	8.10E+03	1.62E+04	3.06E+00	2.55E-06	1.75E-06	5.68E-07	8.71E-08	6.30E-09	2.14E-10
2.35E+00	8.10E+03	1.62E+04	4.48E+00	1.56E-05	1.07E-05	3.49E-06	5.34E-07	3.87E-08	1.32E-09
2.80E+00	8.10E+03	1.62E+04	5.91E+00	7.19E-05	4.94E-05	1.61E-05	2.46E-06	1.78E-07	6.08E-09
3.25E+00	8.10E+03	1.62E+04	7.33E+00	2.30E-04	1.58E-04	5.12E-05	7.86E-06	5.69E-07	1.94E-08
3.70E+00	8.10E+03	1.62E+04	8.75E+00	5.55E-04	3.82E-04	1.24E-04	1.90E-05	1.38E-06	4.70E-08
4.14E+00	8.10E+03	1.62E+04	1.02E+01	1.10E-03	7.56E-04	2.45E-04	3.76E-05	2.72E-06	9.32E-08
4.59E+00	8.10E+03	1.62E+04	1.16E+01	1.88E-03	1.29E-03	4.20E-04	6.45E-05	4.67E-06	1.59E-07
5.04E+00	8.10E+03	1.62E+04	1.30E+01	2.90E-03	2.00E-03	6.48E-04	9.94E-05	7.19E-06	2.46E-07
5.49E+00	8.10E+03	1.62E+04	1.44E+01	4.14E-03	2.85E-03	9.25E-04	1.42E-04	1.03E-05	3.50E-07
5.61E+00	8.10E+03	1.62E+04	1.45E+01	4.14E-03	2.85E-03	9.24E-04	1.42E-04	1.03E-05	3.51E-07
5.76E+00	8.10E+03	1.62E+04	1.45E+01	4.14E-03	2.85E-03	9.24E-04	1.42E-04	1.03E-05	3.51E-07
5.93E+00	8.10E+03	1.62E+04	1.45E+01	4.14E-03	2.85E-03	9.24E-04	1.42E-04	1.03E-05	3.50E-07
6.15E+00	8.10E+03	1.62E+04	1.45E+01	4.14E-03	2.85E-03	9.25E-04	1.42E-04	1.03E-05	3.51E-07
6.41E+00	8.10E+03	1.62E+04	1.45E+01	4.15E-03	2.85E-03	9.26E-04	1.42E-04	1.03E-05	3.52E-07
6.73E+00	8.10E+03	1.62E+04	1.45E+01	4.16E-03	2.86E-03	9.28E-04	1.42E-04	1.03E-05	3.52E-07
7.11E+00	8.10E+03	1.62E+04	1.46E+01	4.17E-03	2.87E-03	9.31E-04	1.43E-04	1.03E-05	3.53E-07
7.58E+00	8.10E+03	1.62E+04	1.46E+01	4.19E-03	2.88E-03	9.36E-04	1.44E-04	1.04E-05	3.55E-07
8.15E+00	8.10E+03	1.62E+04	1.46E+01	4.23E-03	2.91E-03	9.45E-04	1.45E-04	1.05E-05	3.58E-07
8.85E+00	8.10E+03	1.62E+04	1.47E+01	4.29E-03	2.95E-03	9.58E-04	1.47E-04	1.06E-05	3.64E-07
9.70E+00	8.10E+03	1.62E+04	1.47E+01	4.39E-03	3.02E-03	9.80E-04	1.50E-04	1.09E-05	3.71E-07
1.07E+01	8.10E+03	1.62E+04	1.48E+01	4.54E-03	3.12E-03	1.01E-03	1.55E-04	1.12E-05	3.85E-07
1.20E+01	8.10E+03	1.62E+04	1.49E+01	4.78E-03	3.28E-03	1.07E-03	1.63E-04	1.18E-05	4.05E-07
1.35E+01	8.10E+03	1.62E+04	1.50E+01	5.15E-03	3.54E-03	1.15E-03	1.76E-04	1.28E-05	4.36E-07
1.54E+01	8.10E+03	1.62E+04	1.52E+01	5.76E-03	3.96E-03	1.29E-03	1.97E-04	1.43E-05	4.87E-07
1.76E+01	8.10E+03	1.62E+04	1.53E+01	6.76E-03	4.65E-03	1.51E-03	2.31E-04	1.68E-05	5.73E-07
2.04E+01	8.10E+03	1.62E+04	1.56E+01	8.49E-03	5.83E-03	1.89E-03	2.90E-04	2.10E-05	7.18E-07
2.37E+01	8.10E+03	1.62E+04	1.59E+01	1.16E-02	7.95E-03	2.58E-03	3.96E-04	2.87E-05	9.79E-07
2.78E+01	8.11E+03	1.62E+04	1.63E+01	1.73E-02	1.19E-02	3.86E-03	5.92E-04	4.29E-05	1.47E-06
3.27E+01	8.11E+03	1.62E+04	1.68E+01	2.80E-02	1.92E-02	6.24E-03	9.57E-04	6.93E-05	2.36E-06
3.87E+01	8.11E+03	1.62E+04	2.12E+01	3.40E-02	2.34E-02	7.60E-03	1.16E-03	8.44E-05	2.88E-06
4.61E+01	8.11E+03	1.62E+04	2.77E+01	3.83E-02	2.63E-02	8.54E-03	1.31E-03	9.48E-05	3.24E-06
5.50E+01	8.11E+03	1.62E+04	3.60E+01	4.00E-02	2.75E-02	8.93E-03	1.37E-03	9.91E-05	3.39E-06
6.58E+01	8.11E+03	1.62E+04	4.63E+01	3.71E-02	2.55E-02	8.29E-03	1.27E-03	9.20E-05	3.15E-06
7.90E+01	8.11E+03	1.62E+04	5.88E+01	3.05E-02	2.10E-02	6.81E-03	1.04E-03	7.56E-05	2.58E-06
9.51E+01	8.12E+03	1.62E+04	7.33E+01	2.31E-02	1.59E-02	5.16E-03	7.92E-04	5.73E-05	1.96E-06
1.15E+02	8.12E+03	1.62E+04	8.96E+01	1.74E-02	1.19E-02	3.88E-03	5.95E-04	4.31E-05	1.47E-06
1.38E+02	8.13E+03	1.62E+04	1.07E+02	1.37E-02	9.41E-03	3.06E-03	4.69E-04	3.39E-05	1.16E-06
1.67E+02	8.13E+03	1.62E+04	1.26E+02	1.16E-02	7.98E-03	2.59E-03	3.97E-04	2.88E-05	9.83E-07
2.03E+02	8.14E+03	1.62E+04	1.46E+02	1.04E-02	7.14E-03	2.32E-03	3.56E-04	2.58E-05	8.81E-07
2.45E+02	8.15E+03	1.62E+04	1.66E+02	9.42E-03	6.48E-03	2.10E-03	3.22E-04	2.34E-05	7.99E-07
2.97E+02	8.16E+03	1.62E+04	1.87E+02	8.37E-03	5.76E-03	1.87E-03	2.87E-04	2.08E-05	7.11E-07
3.61E+02	8.17E+03	1.62E+04	2.08E+02	7.18E-03	4.94E-03	1.60E-03	2.46E-04	1.78E-05	6.08E-07
4.38E+02	8.18E+03	1.62E+04	2.30E+02	5.94E-03	4.08E-03	1.32E-03	2.03E-04	1.47E-05	5.03E-07
5.32E+02	8.20E+03	1.62E+04	2.53E+02	4.76E-03	3.27E-03	1.06E-03	1.63E-04	1.18E-05	4.03E-07
6.46E+02	8.22E+03	1.62E+04	2.77E+02	3.72E-03	2.55E-03	8.29E-04	1.27E-04	9.21E-06	3.14E-07
7.85E+02	8.25E+03	1.62E+04	3.03E+02	2.85E-03	1.96E-03	6.36E-04	9.75E-05	7.06E-06	2.41E-07
9.54E+02	8.28E+03	1.62E+04	3.32E+02	2.15E-03	1.48E-03	4.81E-04	7.37E-05	5.34E-06	1.83E-07
1.16E+03	8.32E+03	1.62E+04	3.65E+02	1.61E-03	1.11E-03	3.60E-04	5.51E-05	3.99E-06	1.37E-07
1.41E+03	8.37E+03	1.62E+04	4.03E+02	1.20E-03	8.22E-04	2.67E-04	4.09E-05	2.96E-06	1.01E-07
1.71E+03	8.43E+03	1.62E+04	4.46E+02	8.82E-04	6.06E-04	1.97E-04	3.02E-05	2.19E-06	7.49E-08
2.09E+03	8.50E+03	1.62E+04	4.96E+02	6.47E-04	4.45E-04	1.44E-04	2.21E-05	1.60E-06	5.50E-08
2.54E+03	8.59E+03	1.62E+04	5.55E+02	4.74E-04	3.25E-04	1.06E-04	1.62E-05	1.17E-06	4.01E-08
3.09E+03	8.69E+03	1.62E+04	6.24E+02	3.46E-04	2.38E-04	7.71E-05	1.18E-05	8.57E-07	2.93E-08
3.75E+03	8.82E+03	1.62E+04	7.03E+02	2.52E-04	1.73E-04	5.63E-05	8.63E-06	6.25E-07	2.14E-08
4.57E+03	8.97E+03	1.62E+04	7.95E+02	1.84E-04	1.26E-04	4.11E-05	6.30E-06	4.56E-07	1.56E-08
5.55E+03	9.16E+03	1.62E+04	9.01E+02	1.34E-04	9.24E-05	3.00E-05	4.60E-06	3.33E-07	1.14E-08
6.76E+03	9.39E+03	1.62E+04	1.02E+03	9.85E-05	6.77E-05	2.20E-05	3.37E-06	2.44E-07	8.31E-09
8.22E+03	9.67E+03	1.62E+04	1.16E+03	7.23E-05	4.97E-05	1.61E-05	2.48E-06	1.79E-07	6.14E-09
1.00E+04	1.00E+04	1.62E+04	1.32E+03	5.34E-05	3.67E-05	1.19E-05	1.83E-06	1.32E-07	4.53E-09

1

time averaged (tav = 3600. 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	1.97E-01	1.00E+00	8.10E+03	1.62E+04
1.45E+00	7.42E+00	1.00E+00	8.10E+03	1.62E+04
1.90E+00	1.01E+01	8.08E-01	8.10E+03	1.62E+04
2.35E+00	1.20E+01	4.70E-01	8.10E+03	1.62E+04
2.80E+00	1.34E+01	2.96E-01	8.10E+03	1.62E+04
3.25E+00	1.45E+01	2.01E-01	8.10E+03	1.62E+04
3.70E+00	1.54E+01	1.44E-01	8.10E+03	1.62E+04
4.14E+00	1.60E+01	1.08E-01	8.10E+03	1.62E+04
4.59E+00	1.64E+01	8.38E-02	8.10E+03	1.62E+04
5.04E+00	1.67E+01	6.68E-02	8.10E+03	1.62E+04
5.49E+00	1.68E+01	5.45E-02	8.10E+03	1.62E+04
5.61E+00	1.68E+01	5.45E-02	8.10E+03	1.62E+04
5.76E+00	1.68E+01	5.44E-02	8.10E+03	1.62E+04
5.93E+00	1.68E+01	5.44E-02	8.10E+03	1.62E+04
6.15E+00	1.67E+01	5.43E-02	8.10E+03	1.62E+04
6.41E+00	1.67E+01	5.43E-02	8.10E+03	1.62E+04
6.73E+00	1.67E+01	5.42E-02	8.10E+03	1.62E+04
7.11E+00	1.67E+01	5.41E-02	8.10E+03	1.62E+04
7.58E+00	1.67E+01	5.40E-02	8.10E+03	1.62E+04
8.15E+00	1.67E+01	5.38E-02	8.10E+03	1.62E+04
8.85E+00	1.66E+01	5.36E-02	8.10E+03	1.62E+04
9.70E+00	1.66E+01	5.34E-02	8.10E+03	1.62E+04
1.07E+01	1.65E+01	5.31E-02	8.10E+03	1.62E+04
1.20E+01	1.64E+01	5.27E-02	8.10E+03	1.62E+04
1.35E+01	1.62E+01	5.23E-02	8.10E+03	1.62E+04
1.54E+01	1.59E+01	5.17E-02	8.10E+03	1.62E+04
1.76E+01	1.54E+01	5.11E-02	8.10E+03	1.62E+04
2.04E+01	1.48E+01	5.02E-02	8.10E+03	1.62E+04
2.37E+01	1.38E+01	4.92E-02	8.10E+03	1.62E+04
2.78E+01	1.23E+01	4.78E-02	8.11E+03	1.62E+04
3.27E+01	1.02E+01	4.62E-02	8.11E+03	1.62E+04
3.87E+01	7.76E+00	4.42E-02	8.11E+03	1.62E+04
4.61E+01	5.95E+00	4.28E-02	8.11E+03	1.62E+04
5.50E+01	4.54E+00	4.05E-02	8.11E+03	1.62E+04
6.58E+01	3.38E+00	3.78E-02	8.11E+03	1.62E+04
7.90E+01	2.25E+00	3.54E-02	8.11E+03	1.62E+04
9.51E+01	0.00E+00	3.45E-02	8.12E+03	1.62E+04
1.15E+02	0.00E+00	3.33E-02	8.12E+03	1.62E+04
1.38E+02	0.00E+00	3.01E-02	8.13E+03	1.62E+04
1.67E+02	0.00E+00	2.57E-02	8.13E+03	1.62E+04
2.03E+02	0.00E+00	2.09E-02	8.14E+03	1.62E+04
2.45E+02	0.00E+00	1.66E-02	8.15E+03	1.62E+04
2.97E+02	0.00E+00	1.28E-02	8.16E+03	1.62E+04
3.61E+02	0.00E+00	9.77E-03	8.17E+03	1.62E+04
4.38E+02	0.00E+00	7.38E-03	8.18E+03	1.62E+04
5.32E+02	0.00E+00	5.53E-03	8.20E+03	1.62E+04
6.46E+02	0.00E+00	4.12E-03	8.22E+03	1.62E+04
7.85E+02	0.00E+00	3.06E-03	8.25E+03	1.62E+04
9.54E+02	0.00E+00	2.26E-03	8.28E+03	1.62E+04
1.16E+03	0.00E+00	1.66E-03	8.32E+03	1.62E+04
1.41E+03	0.00E+00	1.22E-03	8.37E+03	1.62E+04
1.71E+03	0.00E+00	8.95E-04	8.43E+03	1.62E+04
2.09E+03	0.00E+00	6.54E-04	8.50E+03	1.62E+04
2.54E+03	0.00E+00	4.77E-04	8.59E+03	1.62E+04
3.09E+03	0.00E+00	3.47E-04	8.69E+03	1.62E+04
3.75E+03	0.00E+00	2.53E-04	8.82E+03	1.62E+04
4.57E+03	0.00E+00	1.84E-04	8.97E+03	1.62E+04
5.55E+03	0.00E+00	1.35E-04	9.16E+03	1.62E+04
6.76E+03	0.00E+00	9.86E-05	9.39E+03	1.62E+04
8.22E+03	0.00E+00	7.24E-05	9.67E+03	1.62E+04
1.00E+04	0.00E+00	5.34E-05	1.00E+04	1.62E+04

APPENDIX D

Non-Dense Gas Model Input and Output Files

Table of Contents

USAF TOXIC CHEMICAL DISPERSION MODEL --- AFTOX

Workbook Example 6.15

Hanscom AFB MA
DATE: 08-10-89
TIME: 0300 LST

CONTINUOUS RELEASE

UNSYM. DIMETHYLHYDRAZINE(UDMH)
SHORT TERM EXPOSURE LIMIT(STEL) IS .48 PPM (1.15 MG M-3)
TIME WEIGHTED AVERAGE(TWA) IS .06 PPM (.14 MG M-3)

TEMPERATURE = 10 C
WIND DIRECTION = 270
WIND SPEED = 1 M/S
NIGHTTIME SPILL
CLOUD COVER IS 0 EIGHTHS
THERE IS NO INVERSION
ATMOSPHERIC STABILITY PARAMETER IS 6
SPILL SITE ROUGHNESS LENGTH IS 1 CM

THIS IS A LIQUID RELEASE
EMISSION RATE IS 4.72 KG/MIN
CHEMICAL IS STILL LEAKING
POOL TEMPERATURE IS 10 C
AREA OF SPILL IS 59 SQ M
EVAPORATION RATE IS 3.13 KG/MIN
CONCENTRATION AVERAGING TIME IS 60 MIN
ELAPSED TIME SINCE START OF SPILL IS 60 MIN
ELEVATION IS 0 M
DOWNWIND DISTANCE IS 100 M
CROSSWIND DISTANCE IS 0 M

THE CONCENTRATION IS 220.5 PPM(567.7 MG M-3)

```
   USAF TOXIC CHEMICAL DISPERSION MODEL --- AFTOX

Workbook Example 6.16

Vandenberg AFB
DATE: 08-02-89
TIME: 0300 LST

CONTINUOUS RELEASE

UNSYM. DIMETHYLHYDRAZINE(UDMH)
 SHORT TERM EXPOSURE LIMIT(STEL) IS .48 PPM ( 1.15 MG M-3)
 TIME WEIGHTED AVERAGE(TWA) IS .06 PPM ( .14 MG M-3)
TEMPERATURE = 10 C
WIND DIRECTION = 16
WIND SPEED = 1 M/S
STANDARD DEVIATION OF WIND DIRECTION = 1.37 DEG
WIND AVERAGING TIME = 60 MIN
NIGHTTIME SPILL
CLOUD COVER IS 0 EIGHTHS
THERE IS NO INVERSION
HORIZONTAL STABILITY PARAMETER IS  6
VERTICAL STABILITY PARAMTERE IS 6

SPILL SITE ROUGHNESS LENGTH IS 1 CM

THIS IS A LIQUID RELEASE
EMISSION RATE IS 133.62 KG/MIN
CHEMICAL IS STILL LEAKING
POOL TEMPERATURE IS  10 C
AREA OF SPILL IS 2037 SQ M
EVAPORATION RATE IS 72.13 KG/MIN
CONCENTRATION AVERAGING TIME IS 60 MIN
ELAPSED TIME SINCE START OF SPILL IS 1440 MIN
HEIGHT ABOVE GROUND IS 0 M
DOWNWIND DISTANCE IS 100 M
CROSSWIND DISTANCE IS 0 M
-------------------------------------------------
THE CONCENTRATION IS 7761 PPM( 20046.6 MG M-3)
-------------------------------------------------
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Appendix E

Calculating Temperature of Release Material

Appendix E

Calculating Temperature of Release Material

To correctly utilize dense gas models, it may be important to start the dispersion calculations using the temperature of the released material just after it enters the atmosphere and depressurizes. For a material which is stored under pressure, this requires an estimate of the release temperature immediately after it expands to atmospheric pressure. For a liquid which is stored under pressure above its normal boiling temperature, the release will be accompanied by flashing, and the release temperature may be conservatively assumed to equal the normal boiling temperature. It should be noted that a flash calculation should be performed for this situation to determine the relative amounts of liquid and vapor in the initial release.

If the released material can be represented as an ideal gas both before and after depressurization, then the temperature of the contaminant is unchanged during an isenthalpic expansion. Such ideal gas behavior can be expected for low-to-moderate storage pressure and temperature and when the pressure and temperature are not near the critical pressure and temperature, respectively.

If the contaminant cannot be represented as an ideal gas both before and after depressurization, then the temperature of the contaminant must be determined from thermodynamic properties of the released gas. Thermodynamic properties are generally presented in one of two forms: in tables or in figures. These examples demonstrate the pertinent calculations (for nonideal gases) for both data types.

<u>Chlorine Example</u>

For this example, chlorine gas at 6 atm and 298 K is to be released to atmospheric pressure. Since the initial pressure of 6 atm could be considered to be out of the low-to-moderate pressure range, ideal gas behavior may not be justified for these conditions.

Isenthalpic depressurization simply means that the enthalpy of the gas is unchanged between the initial and final states. If H_i and H_f denote the initial and final enthalpies of the gas, respectively, then isenthalpic depressurization implies that $H_i=H_f$. From Perry's handbook (Perry and Green, 1984), the properties for chlorine are given in tabular form; part of the table is shown in Table 1. The table shows the enthalpy (H*) and temperature (T*) for chlorine vapor under saturation conditions.

Table 1

Temperature Versus Enthalpy for Chlorine Vapor

Temperature °F	Temperature K	Pressure lb./sq. in.	Enthalpy B.t.u./(lb)(°F)
-29.29		14.696	225.86
60		85.606	233.64
80		116.46	235.03

*Based on Table 3-229 chlorine, p. 3-184, Perry's Handbook, Sixth Edition

Using this information, the initial and final enthalpies can be represented as:

$$H_i = H^*(P_i) + C_p\ (T_i - T^*(P_i))$$

$$H_f = H^*(P_f) + C_p\ (T_f - T^*(P_f))$$

where $H^*(P_i)$ and $H^*(P_f)$ represent the enthalpy of saturated chlorine vapor at the initial and final pressures, respectively. Likewise, $T^*(P_i)$ and $T^*(P_f)$ represent the temperature of saturated chlorine vapor at the initial storage pressure (6 atm x 14.696=88.176 lb./sq. in.) and final pressure (1 atm x 14.696=14.696 lb./sq. in.). From the table, $H^*(P_i)$=233.77 BTU/lb., $T^*(P_i)$=289.74K (or 62.13°F), $H^*(P_f)$=225.86 BTU/lb., and $T^*(P_f)$=239.1 K (or -29.01°F). (For interpolation, log(P) can be linearly interpolated with 1/T* where T* is in absolute temperature, and H* can be linearly interpolated with T*). With these values and the heat capacity for chlorine (taken to be 0.214 BTU/lb. K), T_f is 284.3 K.

If the initial state of 6 atm had been considered to be a low-to-moderate pressure, and since the initial state is not near the critical conditions for chlorine (76.1 atm and 417 K), then ideal gas behavior for both initial and final states would have been justified, and the final chlorine temperature would be equal to the initial state temperature or 298 K. This assumption would have resulted in an error of 4.8% in the density estimate for input to the dispersion model.

First Propylene Example

For this example, propylene gas at 29 bar (28.6 atm) and 343.15 K is to be released to atmospheric pressure. Since the initial pressure of 29 bar could be considered to be out of the low-to-moderate pressure range, ideal gas behavior may not be justified for these conditions. (Also, the initial state is near the critical state of 46.41 bar and 365.1 K.)

In Perry's handbook, sixth edition, (page 3-219, Figure 3-32), the properties for propylene are given in both a table and a figure. Once again, isenthalpic expansion from the initial to final state implies $H_i=H_f$. Using the figure, the initial enthalpy is found to be approximately 1100 kJ/kg using the initial pressure (29 bar) and initial temperature (343.15 K). The final temperature can now be found by using the final pressure (1.01325 bar) and the final enthalpy (1100 kJ/kg -- since $H_i=H_f$); the final temperature is approximately 285 K.

If ideal gas behavior for both initial and final states had been assumed, the final propylene temperature would have been 343.15 K. This assumption would have resulted in an error of 20% in the density estimate for input to the dispersion model.

Second Propylene Example

For this example, propylene gas at 5 bar (4.9 atm) and 303.15 K is to be released to atmospheric pressure. Since the initial pressure and temperature could be considered to be in the low-to-moderate range, and since the initial state is not near the critical conditions, ideal gas behavior may be justified for these conditions. If ideal gas behavior is assumed for both initial and final states, the final (depressurized) propylene temperature would be 303.15 K.

As a check, the properties for propylene can be applied to this example. Once again using the figure discussed above, the initial enthalpy is found to be approximately 1100 kJ/kg using the initial pressure (5 bar) and initial temperature (303.15 K). The final temperature can again be found by using the final pressure (1.01325 bar) and the final enthalpy (1100 kJ/kg -- since $H_i=H_f$); using this method, the final temperature is approximately 293 K.

If ideal gas behavior for both initial and final states had been assumed, the density estimate for the dispersion model would be in error by 3.4%.

References

Perry, R. H. and D. W. Green, eds., "Perry's Chemical Engineer's Handbook," Sixth Edition, McGraw-Hill, 1984.

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-450/4-91-007	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Guidance on the Application of Refined Dispersion Models for Air Toxics Releases		5. REPORT DATE March 1991 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Source Receptor Analysis Branch U.S. Environmental Protection Agency Research Triangle Park, NC 27711		10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS		13. TYPE OF REPORT AND PERIOD COVERED Final Report 14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

EPA Contact: Jawad S. Touma

16. ABSTRACT

Refined air toxics models are increasingly being used to assess the impact of toxic air pollutants released into the atmosphere. The purpose of this guidance document is to provide general guidance considerations for applying dispersion models to such releases and to show the thought process required by the non-expert user to develop all model input parameters. Two example applications for each model are provided with a step-by-step explanation of all model input parameters and model output. Four specific models are currently included in the document. These are the DEGADIS, HEGADAS, and SLAB models appropriate for denser-than-air releases and the AFTOX model for neutrally buoyant releases of toxic air pollutants.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air Pollution Hazardous Waste Assessments Toxic Air Pollutants Dense Gas Models Air Quality Dispersion Models	Dispersion Modeling Meteorology Air Pollution	13B

18. DISTRIBUTION STATEMENT Release Unlimited	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 165
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

EPA Form 2220-1 (9-73)