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GUIDELINE FOR AMBIENT IMPACT ASSESSMENT OF TOXIC AIR POLLUTANT EMISSIONS

GEORGIA DEPARTMENT OF NATURAL RESOURCES
ENVIRONMENTAL PROTECTION DIVISION
AIR PROTECTION BRANCH

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Purpose and Scope of the Guideline for Toxic Air Pollutant Emissions

The purpose of this document is to provide a guide for estimating the environmental impact of sources of toxic air pollutants. A toxic air pollutant is defined as any substance which may have an adverse effect on public health, excluding any specific substance that is covered by a State or Federal ambient air quality standard.

The guidelines will be used in the review of all air quality applications for permit to construct/modify potential sources of air pollutants and in other cases at the Director's discretion. The guidelines may also be employed to estimate the environmental impact of toxic air pollutants in any situation where approved ambient monitoring data is not available.

The reader should note that there are several steps which can be involved in conducting an air toxics review using these guidelines. The first step, and the one for which the most detail is provided in these guidelines, involves the calculation of an acceptable ambient concentration (AAC), modeling of a predicted ambient impact, and comparing the modeled result with the AAC. The vast majority of permit applications "pass" the guidelines at this point and require no further analysis. This first step can be thought of as a "screening" step after which more in depth analysis may be necessary. These additional steps include 1) a site specific risk assessment, 2) the use of alternative toxicity data, safety factors, or methods of impact assessment, and 3) the installation of New Source MACT. It should be noted that supplying the information necessary for these additional levels of review is the responsibility of the applicant and are subject to review and approval by the Division.

The Director of the Environmental Protection Division approved the use of these guidelines by the Air Protection Branch on September 10, 1984 under the provisions of Rule 391-3-1-.02(2)(a)3.(ii) of the Georgia Rules for Air Quality Control. The 1984 guidelines were revised and approved for use on April 11, 1994. The guidelines have been further revised as presented in this document and have been approved for use under the above stated provisions on September 25, 1998. This current version of the guidelines supersedes all previous versions.

Special Note:

It is the applicant's responsibility to recommend, and provide supporting documentation for, any site specific risk assessments or alternative toxicity data and/or safety factors different from the ones recommended in these guidelines. The use of any such risk assessment procedures, alternative toxicity data, safety factors, or methods of impact assessment is subject to approval by the Division. The Director may approve an application that includes the installation of New Source MACT if it is infeasible for the applicant to comply with the acceptable ambient concentrations found in this guideline. For the purpose of this guideline “New Source MACT” is defined as the control technology which reflects the maximum degree of reduction in emissions of hazardous air pollutants that the Director, taking into consideration the cost of achieving such emission reduction, and any non-air quality health and environmental impacts and energy requirements, determines is achievable by the source, provided that such control technology is no less effective than the level of emission control which is achieved in practice by the best controlled similar source.

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Guideline for Ambient Impact Assessment of Toxic Air Pollutant Emissions

I. REQUIRED DATA

To perform an impact assessment of toxic air pollutants, certain information is necessary. This information is used for estimation of the maximum ground-level concentration (dispersion analysis), and calculation of the acceptable ambient concentration. Some data may come from the permit application and other data may be derived from reference materials. If the permit application data appears confusing, ambiguous, or incorrect, a written confirmation of the data should be requested from the permit applicant. The information needed is as follows:

1. Description of Toxic Air Pollutants to be Emitted

   The pollutants should be described by the standard chemical nomenclature of the Chemical Abstract Service (CAS). Use of standard nomenclature provides information on elemental composition, and is the nomenclature most often used in reference materials on toxicity. Trade Names of toxic air pollutants provide no useful information but may be traced to the standard nomenclature (see Part V., Reference Material).

2. Height Above Ground Level of Toxic Pollutant Release Point

   For use in dispersion analysis and in units of meters (m). This is normally the height of the stack exit above ground level.

3. Pollutant Stack Gas Temperature (°K), Stack Gas Velocity(m/sec), Inside Stack Diameter (m)

   For calculation of plume rise in dispersion analysis. These parameters allow the calculation of the effective plume rise from buoyancy and momentum.

4. Maximum Toxic Pollutant Emission Rate

   This should always be converted to grams per second (g/s) for use in dispersion analysis. This value should be the maximum emission rate expected under normal worse case conditions. This maximum emission rate is determined using the following methods.

   A. **When Performing 24-hour and 15-minute Evaluations**

      (i) For processes whose emissions are relatively constant (continuous processes) - The maximum emission rate is the maximum 1-hour average emission rate during worse case conditions. If 1-hour average maximum emission rates are not available use the shortest time period available.

(ii) For processes whose emissions vary significantly over time (batch processes) -

(a) 24-hour evaluations - The maximum emission rate is total emissions during the worse case batch divided by the length of the batch. The length of the batch does not include down time between batches.

(b) 15-minute evaluations - The maximum emission rate is the emission rate during the highest emitting portion of the batch. For facilities which have numerous batch processes, the maximum emission rate should be based on the batch process which has the highest emission rate. Batch processes which routinely emit simultaneously should be considered together when determining the maximum emission rate to use in the evaluation. When a process emits more than one toxic pollutant, a maximum emission rate should be determined for each pollutant separately.

B. **When Performing Annual Evaluations**

(i) For processes whose emissions are relatively constant (continuous processes) - the maximum emission rate is the total annual emissions that would occur if the process is operating under worse case conditions and full capacity for the entire year divided by 8760 hours/year.

(ii) For processes whose emissions vary significantly over time (batch processes) - The maximum emission rate is the total emissions from the worse case batch times the maximum number of batches per year divided by 8760 hours/year.

Please note that emissions estimates with low confidence levels (i.e. based on less reliable data) may take longer to process and may result in a Permit that contains emissions limits and source test requirements. If the permit applicant does not use source testing or monitoring data for their emissions estimates, then reliable methods should be used to calculate emission rates and full documentation of all calculations included with the application.

5. Hours Per Week (hr/wk) and Hours Per Day (hr/day) of Toxic Pollutant Emission

For use in dispersion analysis and in calculation of acceptable ambient pollutant concentration. These values should be for the maximum amount of operational time for which the applicant has applied.

6. Source Location and Facility Property Boundaries

For use in dispersion analysis. This information will be used to assure that the toxic evaluation will occur at a location off the property of the facility, provided that the general public does not have ready access (as defined on page 7) to any portion of the property.

7. Pollutant Toxicity Data

Necessary for derivation of the acceptable ambient concentration. Some of the best known rating systems for material toxicities are as follows:

A. **Integrated Risk Information System (IRIS)** - unit risk presented as a risk per concentration $(ug/m^3)^{-1}$ and/or an inhalation reference concentration (RfC) in units of mg/m^3. Use unit risk estimates to calculate the risk based air concentration (RBAC) that provide a cancer risk of 1 in 1,000,000 for pollutants with an IRIS weight-of-evidence classification of A, 1 in 100,000 for pollutants with an IRIS weight-of-evidence classification of B, and 1 in 10,000 for pollutants with an IRIS weight-of-evidence classification of C. The RBAC is calculated by dividing the cancer risk by the unit risk. The results of this calculation are generally presented in IRIS. Both the RfC and RBAC are given as an annual average.

B. **Occupational Safety and Health Administration Time Weighted Average and Ceiling Permissible Exposure Limit Standards (PEL-TWA, PEL-C) -** a maximum permissible limit of exposure to toxic materials. Required by Federal regulations for use in the work place. The PEL-TWA is a concentration standard averaged over an 8-hour time period. Usage of the TWA standard is based on an exposure period of eight hours per day, five days per week exposure period. Concentrations designated "C" (ceiling limit) are based on a 15-minute average.

C. **Threshold Limit Values (TLV-TWA, TLV-STEL, TLV-C) -** from ACGIH (American Conference of Governmental and Industrial Hygienists). A concentration below which no irreversible toxic effects are expected. TLV-TWA is a concentration standard averaged over an 8-hour time period. A suggested standard prepared for use in the work place (occupational health). Concentrations designated STEL (short term exposure limit) or "C" (ceiling limit) are based on a 15-minute average.

D. **National Institute for Occupational Safety and Health (NIOSH) Recommended Standards (REL-TWA, REL-STEL, REL-C) -** a Federal research organization responsible for assessing material toxicity, and recommending standards for occupational exposure. The recommended standards (REL-TWA) are usually expressed as an 8-hour time weighted average concentration similar in form to the OSHA TWA-PEL. Concentrations designated STEL (short term exposure limit) or "C" (ceiling limit) are based on a 15-minute average.

E. **LD50 (Lethal Dose -50%)** - A terminology used in toxicology research. LD50 is the dose of a substance introduced which is expected to cause the death of 50% of an experimental animal population. The LD50 is normally expressed in milligrams, grams, micrograms, or nanograms of toxic material per kilogram of animal weight.

F. Other documented sources of toxicity data (i.e. Material Safety Data Sheets and other toxic studies).

The above types of toxicity data may be found for the majority of common toxic pollutants in available reference materials. A listing of these references are found in Part V. of this guideline.

II. DISPERSION ANALYSIS

A dispersion analysis must be performed to estimate the expected maximum toxic pollutant concentration downwind of the release point. The data listed in Part I. of this guideline are the minimum required for performance of the dispersion analysis.

The analysis of dispersion is by mathematical modeling. The model currently of greatest utility is the Gaussian plume distribution model. A discussion of this model may be found in the Workbook of Atmospheric Dispersion Estimates, by D. B. Turner. Study of this workbook is recommended for an understanding of the assumptions and limitations inherent in the model.

For simplicity, the use of the Gaussian mathematical model is recommended for pollutant concentration at the plume centerline and at ground level downwind. This model is described by:

$$X = \frac{Q}{\pi \sigma_y \sigma_z u} \exp\left[-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right]$$

where:
- X - centerline, ground-level concentration, g/m^3
- u - wind velocity, m/s
- Q - maximum emission rate, g/s
- H - effective stack height, m
- σ_y, σ_z - dispersion parameters, m

The effective stack height, H, is the sum of the stack height and plume rise. Plume rise may be calculated from Briggs' equation found in Appendix A. The data listed in section 3. of Part I. are used in the Briggs' equation. The parameter u (wind velocity) found in the Briggs' equation should be the same as that assigned to the u variable in the denominator of the Gaussian plume model. The dispersion parameters σ_y and σ_z in the Gaussian model are also variables.

1. Computer Solution of the Gaussian Model

The general method of model solution is by trial and error. The variables σ_y, σ_z are varied according to downwind distance and atmospheric stability, while u is varied for each set of σ_y,σ_z values. This repetition or "reiteration" is most efficiently accomplished by computer. The SCREEN3 or ISC3 computer programs currently in use by the State will produce solutions to the Gaussian model. Additionally, the TSCREEN model may be used to assist in the computer simulation of certain toxic release scenarios subject to State approval. New U.S. Environmental Protection Agency (U.S. EPA) approved computer programs will be incorporated as they become available. Use of U.S. EPA recommended models other than those referred to in this Guideline must be approved by the Division.

In addition, if the source is located in an area with complex terrain, one of the following computer programs may be used (in the best judgement of the Division):

ISCST3, CTSCREEN; VALLEY; or Valley option of COMPLEX 1

The U.S. EPA SCREEN3 and ISC3 computer models may be obtained in diskette form from the National Technical Information Service (NTIS), Springfield, Virginia, 22161 or downloaded from the Technology Transfer Network (TTN) of EPA's Office of Air Quality Planning and Standards (OAQPS). The latest versions of these models shall be used. Due to safety factors built into the this Guideline, the Division does not require the use of downwash calculations in any dispersion modeling procedures. The Division reserves the right to require the inclusion of downwash calculations if they are warranted by specific conditions.

A. **Screening Modeling Procedures** - An initial simplified evaluation of air toxic impacts can be made with the SCREEN3 model. Recommendations for each SCREEN3 run are as follows:

(i) The maximum toxic pollution emission rate (expressed as a 1-hour average) for each pollutant should be used. These values should be determined by procedures outlined in section I.4.

(ii) The option for flagpole receptors should generally not be used.

(iii) Choose the rural or urban dispersion option based on the procedure in U.S. EPA's "Guideline on Air Quality Models (Revised)". The rural option is appropriate for most locations in Georgia.

(iv) Choose the default atmospheric temperature of 293K.

(v) For each release, exercise the automated distance array choosing as the minimum receptor distance the appropriate nearest fence line distance for that release. The maximum concentration for that release will then be chosen as the maximum calculated concentration at or beyond the nearest fence line distance.

(vi) For each release, the maximum 1-hour concentration should be noted. Adjustments to the appropriate averaging period (subsection IV.1.B.) should be made using the factors in subsection D. of this Part.

B. **Refined Modeling Procedures** - If screening modeling indicates an unacceptable air quality impact using the procedures in Part IV., then refined modeling is recommended. The ISCST3 computer program should be used to predict maximum short-term concentrations (time periods of 24 hours or less). ISCST3

may also be used to generate maximum annual concentrations except that when modeling for a toxic air pollutant for which only an annual exposure is applicable, in such cases the ISCLT3 computer program must be used. The ISCST3 and ISCLT3 models are known collectively as ISC3.

In addition to the required data listed in Part I., the ISC3 modeling analysis requires the following:

(i) Five years of meteorological data from the nearest National Weather Service (NWS) station. Contact the State Agency for identification of an acceptable data set. Acceptable NWS data are generally available through the U.S. EPA Technology Transfer Network. Alternatively, one or more years of meteorological data from on-site measurements may be substituted. These data should be obtained and quality-assured using procedures consistent with the U.S. EPA "Guideline on Air Quality Modeling (Revised)."

(ii) Plant layout information, including all emission point and fence line locations. This information should be sufficiently detailed to allow the modeler to specify emission point and fence line receptor locations within 2 meters of their actual locations.

Modeling may be conducted using either a polar or rectangular receptor grid, but with sufficient detail to accurately estimate the highest concentration from each source. Each ISC3 run should include recommendations (i)-(iii) from the Screening Modeling Procedures above. In addition, the regulatory default option should be selected.

C. **Exclusion of Pollution Concentrations Located on Facility Property** - Note that solution of the model by computer will produce a series of pollutant concentrations at specific stabilities, wind speeds and downwind distances. It is recommended that concentrations located inside of the facility boundaries be excluded from the impact assessment provided that the general public does not have ready access to any portion of the property. Examples of areas with ready access to the public are:

- Commonly used roads
- Rivers used by boaters or fishermen
- Areas with picnic tables or jogging trails

A scaled plot plan of the facility boundaries, with the emission points located on the plan, may be used to determine which concentrations are located on facility property. These concentrations should be excluded and the maximum concentration found outside of facility property selected for further use in the impact assessment. If the concentration could be both on or off property, depending on wind direction, consider it off property.

D. **Adjustment of Off-Property Maximum Pollutant Concentration to Correct Averaging Time** - In order to compare the maximum off-property pollutant concentration with the acceptable ambient concentration, the averaging times for both should be the same. The averaging time for the acceptable ambient toxic pollutant concentration will be defined as an annual average for pollutant toxicity data acquired from RBAC and RfC data, as referenced in A. of section 1. of Part III., as a 24-hour average for pollutant toxicity data acquired from TWA's as referenced in B. through E. of section 1. of Part III., and as a 15-minute average for both STEL's or Ceiling Limits. If the pollutant has an RBAC and/or an RfC and also a ceiling limit or STEL, then both an annual and a 15-minute concentration should be calculated. If a pollutant has both an 8-hour TWA and a ceiling or STEL, then both a 24-hour and 15-minute concentration shall be evaluated. The method for comparison of the toxicity values will be more fully discussed in Part IV. of the guideline.

The maximum ground-level concentrations produced from the Gaussian dispersion model by the SCREEN3 computer program are estimated to be valid for an averaging period of 1 hour. Factors for adjusting the 1-hour average concentrations to applicable averaging periods are listed below:

Averaging Time	Multiplying Factor
15 minutes	1.32
24 hours	0.40
annual	0.08

In the case where emissions occur less than 24 hours per day, an additional adjustment to the 24-hour concentration is required and is described in subsection E., below.

Further information on adjusting 1-hour concentrations to different averaging periods can be found in Appendix D of EPA-454/R-92-024, "Workbook of Screening Techniques for Assessing Impacts of Toxic Air Pollutants (REVISED)."

The ISCST3 computer program is capable of providing concentrations for averaging periods of 1-hour and longer and does not require averaging time adjustment except (1) when evaluating a STEL or ceiling value (use the factor above for 15 minutes) and (2) in the case of emissions which occur less than 24 hours per day.

E. The recommended formula for adjustment of modeled concentrations when emissions occur less than 24 hours per day is:

$$C_e = C_c(y/1440)(1440/y)^{0.2} = C_c\,(y)^{0.8}\,(2.97 \times 10^{-3})$$

where: C_e is emission adjusted 24-hour concentration
C_c is calculated 24-hour concentration
y is minutes of emissions per 24 hours

This adjustment factor is applicable for both SCREEN3 and ISCST3 modeling results.

2. Manual Estimation of Maximum Pollutant Concentration from the Gaussian Model

The goal in manual estimation is the same as that desired from computer estimation - a derivation of the maximum ground-level pollutant concentration. A full manual trial and error solution to the Gaussian dispersion equation should give the same result as solution by computer. It is not recommended that a full manual trial and error procedure be used. Such a procedure would require an unreasonable expenditure of time given the availability of computer programs.

There are abbreviated manual methods for determining the maximum ground-level pollutant concentration. These procedures will be called "screening methods." One type of screening method is found on page 17, with Figure 3-9, of the Turner workbook. For a given maximum emission rate (Q), the maximum concentration (C) and distance from source (x) may be derived. Values for the variables u, H, and the stability type must be assigned by the reviewer. Another short method for maximum concentration determination is Figure 31 of the U.S. EPA document "Estimation of Permissible Concentrations of Pollutants for Continuous Exposure." This nomograph is reproduced in Appendix B of this guideline. The reviewer must assign values to the variables u (wind speed), H (effective stack height), and stability category.

The values assigned to the variables of the screening methods should be chosen such that the resultant maximum concentrations are equal to or greater than those concentrations derived by computer. A wind speed of 0.5 meters per second, no plume rise for effective stack height, and selection of the stability giving highest concentrations for the given stack height should result in a maximum concentration equal to or greater than that found by computer. Maximum concentrations produced from the screening methods should be adjusted to a 1-hour average first and then adjusted to the appropriate averaging time using the factors in subsection 1.D. of this Part. To convert the 10-minute average from the nomograph to a 1-hour average, divide by 1.43. If necessary, an adjustment for emissions less than 24 hours per day should be made using the procedures in subsection 1.E. of this Part. Exclusion of maximum concentrations from facility property (subsection 1.C. of this Part) are not possible with the nomograph screening method and are often difficult with the Turner screening method. It is recommended that the location of maximum concentrations derived by the screening methods not be a consideration when using the screening methods for impact assessment. A priority system for use in impact assessment is discussed in Part IV. of the guideline.

3. Summary

A dispersion analysis must be performed to derive the expected maximum ambient pollutant concentration. The recommended dispersion model is the Gaussian plume distribution model. The analysis may be performed by either manual or computer methods. It is recommended that the manual methods be limited to simplified "screening methods" and used only when computer methods are unavailable. The results of both methods should be corrected to the appropriate averaging period. An adjustment is made to the 24-hour ambient impact if emissions occur less than 24 hours per day. In the computer methods, maximum concentrations located on facility property will be excluded from the impact assessment. The results of any manual methods should reflect potential worst case conditions.

III. ACCEPTABLE AMBIENT POLLUTANT CONCENTRATION

1. Acquisition of Pollutant Toxicity Data

An acceptable ambient concentration must be developed for each toxic air pollutant emitted. The basis for calculation of the acceptable ambient concentration comes from the pollutant toxicity rating systems listed in section 7. of Part I. It is recommended that toxicity data be used according to the following priority schedule. The reviewer should use the most recent version of each reference that is available at the time of the review.

A. **Integrated Risk Information System (IRIS)** - Unit risk is presented as a risk per concentration $(ug/m^3)^{-1}$ and/or an inhalation reference concentration (RfC) in units of mg/m^3. Use unit risk estimates to calculate the risk based air concentration (RBAC) that provide a cancer risk of 1 in 1,000,000 for pollutants with an IRIS weight-of-evidence classification of A, 1 in 100,000 for pollutants with an IRIS weight-of-evidence classification of B, and 1 in 10,000 for pollutants with an IRIS weight-of-evidence classification of C. The RBAC is calculated by dividing the cancer risk by the unit risk. The results of this calculation are generally presented in IRIS. Inhalation reference concentration (RfC) is in units of mg/m^3. Both the RfC and RBAC are given as an annual average.

B. **OSHA Standards (PEL's)** - Should be converted to units of mg/m^3. These are found in 29 CFR Part 1910 Subpart Z. Use ceiling limits for acute sensory irritant and toxic evaluations based on a 15-minute average. Eight-hour time weight averages (TWA) are used for chronic effect evaluations based on a 24-hour average. The most recently published value should be used.

The recommended conversion formula to be used when the limit is given in units of parts per million (ppm) is:

$$C\ (mg/m^3) = C\ (ppm) \times (MW) \div 24.45$$

where:

C - Concentration of pollutant in air in units of mg/m^3 or ppm.
MW - Molecular weight of the pollutant in units of grams/gram-mole
24.45 - Molar volume at 25°C and 760 mmHg

C. **ACGIH Recommendations (TLV's)** - Should be converted to units of mg/m^3. Use short term exposure limits (STEL) or ceiling limits for acute sensory irritant and toxic evaluations based on a 15-minute average. Eight-hour time weight averages (TWA) are used for chronic effect evaluations based on a 24-hour average. The most recently published value should be used.

D. **NIOSH Recommended Standards (REL's)** - The 8-hour time weighted averages (TWAs) should be converted to units of mg/m^3. Use short term exposure limits (STEL) or ceiling limits for acute sensory irritant and toxic evaluations based on a 15-minute average. Some of the NIOSH TWAs are available in the NIOSH Pocket Guide to Chemical Hazards (NPG). All of the NIOSH TWAs are available in the Registry of Toxic Effects of Chemical Substances (RTECS) Database. Updated RTECS data is available from various sources on CD-ROM, On-line Computer, or Computer Tape.

E. **LD50 Toxicity Data** - Available in the NIOSH database called the Registry of Toxic Effects of Chemical Substances (RTECS). Updated RTECS data is available from various sources on CD-ROM, On-line Computer, or Computer Tape. LD50 data must be converted to a standard equivalent to an 8-hour TWA. Note that the use of an LD50 for derivation of an AAC is the least desirable approach and should only be used if none of the above toxicity data is available. If STEL or Ceiling data can be obtained from one of the previous sources, the LD50 should not be used to calculate an AAC. The recommended conversion formula is:

$$\text{TWA in mg/m}^3 = 0.029 \text{ (LD50 in mg/kg)}$$

From "Estimation of Permissible Concentrations of Pollutants for Continuous Exposure," page 37, EPA-600/2-76-155.

If none of the above toxicity data can be located in available references for a particular pollutant, further research by the permit applicant should be requested.

2. <u>Adjustment of Toxicity Data for Potential Public Exposure in Excess of Occupational Exposure</u>

A. The pollutant toxicity data acquired from RBAC and RfC data, as referenced in A. of section 1. of this Part, has already been determined as an annual average pollutant exposure limit. For purposes of evaluating the pollutant impact using these estimates, the toxicity data acquired does not need to be changed.

B. The pollutant toxicity data acquired from TWA's as referenced in B. through E. of section 1. of this Part are usually based on a 40 hour per week pollutant exposure. Many sources operate more than 40 hours per week subjecting the public to exposure to toxic pollutant emissions for more than 40 hours per week.

Therefore, it is required that this type of toxicity data be adjusted to account for emissions that occur more than 40 hours per week. The adjustment accounts for potential public pollutant exposure and uptake in excess of that exposure (40 hours per week) upon which the TWA's are based. The recommended adjustment formula is:

$$T_A = T_O (40/X)$$

where:

X - number of hours per week emissions occur
T_O - TWA data from references B. through E., section 1. of Part III.
T_A - toxicity data adjusted for exposure greater than 40 hours per week.

The toxicity data should not be adjusted in cases where emissions occur less than 40 hours per week or when using a STEL or ceiling limit.

3. Application of the Safety Factor

A. The toxicity data acquired from RBAC and RfC data, as referenced in A. of section 1. of this Part, does not need the application of a safety factor to account for exposure to persons with respiratory maladies, young children or the elderly, since these have already been considered in the determination of these values. In this case the acceptable ambient concentration (AAC) is the same value as the RBAC or RfC.

B. The exposure adjusted toxicity data acquired from TWAs, STELs, or ceiling limits as referenced in B. through E. of section 1. of this Part, is further adjusted by application of a safety factor. The safety factor accounts for pollutant exposure to members of the public who may be more sensitive to pollutant effects (persons with respiratory maladies, young children or the elderly) than the average citizen. The recommended formula for application of the safety factor is:

$$AAC = T_A \div \text{safety factor}$$

where:

AAC - acceptable ambient pollutant concentration
T_A - exposure adjusted toxicity data from section 2. of this Part.

The safety factor recommended for adjusting TWA's for pollutants which are not known human carcinogens is 100. For **known** human carcinogens the recommended safety factor for adjusting TWA's is 300. The safety factor recommended for acute sensory irritants (those pollutants with ceiling limits or STEL's) is 10.

4. The Acceptable Ambient Pollutant Concentration Averaging Period

A. When using the pollutant toxicity data acquired from RBAC and RfC data, as referenced in A. of section 1. of this Part, the averaging period for the acceptable ambient concentration is defined as an annual average.

B. When using the pollutant toxicity data acquired from TWA's, as referenced in B. through E. of section 1. of this Part, the averaging period for the acceptable ambient concentration (AAC) will be defined as 24 continuous hours. The averaging period for the AAC is defined to be 15 minutes when using a STEL or ceiling limit value.

5. Summary

An acceptable ambient concentration (AAC) is developed for each toxic air pollutant. Toxicity data is acquired from a priority list of references (section 1.). The toxicity data is adjusted for potential public exposure if the emissions are emitted in excess of 40 hours per week (section 2.) when using the pollutant toxicity data acquired from an 8-hour Time Weighted Average (TWA). When using the pollutant toxicity data acquired from RBAC and RfC data, it is not necessary to adjust the concentration for potential public exposure since this has already been addressed. A further adjustment is made by application of a safety factor (section 3.) when using the pollutant toxicity data acquired from TWA's, STEL's, and ceiling limits. This results in the acceptable ambient concentration (AAC). A safety factor is not necessary when using pollutant toxicity data acquired from RBAC and RfC data since safety factors have already been incorporated (the AAC has the same value as the RBAC or RfC). The result of the section 3. adjustment is the acceptable ambient concentration. The resulting AACs will be used in the Impact Determination of Part IV.

An acceptable ambient concentration (AAC) should be developed (from STEL and ceiling limit data) to account for acute sensory irritants and toxics. For acute sensory irritants and toxics, an acceptable ambient concentration (AAC) is developed for the toxic air pollutant. Toxicity data is acquired from a priority list of references (section 1.). The toxicity data derived from a ceiling limit or STEL is adjusted by the application of a safety factor of 10. The result of the adjustment is an acceptable ambient concentration, as a 15-minute average. This AAC should also be used in the Impact Determination of Part IV.

The recommended use of toxicity data and safety factors in calculating acceptable ambient concentrations does not preclude the use of alternative or new toxicity research data. Use of such alternative data should be supported by documentation. Please note that the toxicity data used in this Guideline is routinely revised. The Division reserves the right to set acceptable ambient concentrations which differ from that which would be calculated using the Guideline as it deems appropriate.

IV. DETERMINATION OF TOXIC AIR POLLUTANT IMPACT

The general procedure for determination of toxic air pollutant impact is a simple comparative method. The maximum ground-level concentration (MGLC) found by dispersion analysis (Part II.) is compared to the acceptable ambient concentration (AAC) (Part III.) for the pollutant. If the AAC is developed from a RBAC or Reference Concentration, it is compared with an annual MGLC. If a 24-hour or 15-minute AAC is a derived from one of the other sources (OSHA PEL, ACGIH TLV, NIOSH REL, or LD50) it is compared with a 24-hour or 15-minute MGLC. If the MGLC is less than the AAC, there is indication that toxic air pollutant impact will be insignificant. An MGLC greater than the AAC indicates a potential public health problem.

1. Method for Assessment of Impact

It is recommended that the maximum ground-level concentrations derived from computer dispersion analyses or manual method (Part II.) and derivations of acceptable ambient pollutant concentrations (Part III.) be employed in the impact assessment according to the following schedule~~s~~.

A. First, derive acceptable ambient concentration (AAC).

(i) If the pollutant has a RBAC or a Reference Concentration (RfC), then the AAC is the same value as the RBAC or Reference Concentration. If the pollutant has both a RBAC and an RfC, then the AAC is the lower of the two. If the pollutant has a RBAC or RfC and also has a ceiling limit or STEL, then both an annual AAC (from RBAC or RfC) and a 15-minute AAC (from the ceiling limit or STEL) should be calculated.

(ii) If the pollutant does not have a RBAC or a Reference Concentration (RfC), then derive an acceptable ambient concentration (AAC) using the OSHA PEL, ACGIH TLV, NIOSH REL, or LD50 and the procedures in Part III. If a pollutant has both an 8-hour TWA and a ceiling limit or STEL both a 24-hour AAC and 15-minute AAC should be calculated. If OSHA has a 15-minute ceiling limit of STEL but no 8-hour TWA, use the OSHA 15-minute limit and obtain an 8-hour TWA from ACGIH or NIOSH. If OSHA has no toxicity data and ACGIH has a 15-minute ceiling limit or STEL but no 8-hour TWA, use the 15-minute limit from ACGIH and obtain an 8-hour TWA from NIOSH.

B. Derive maximum ground-level pollutant concentration (MGLC) using SCREEN3 computer dispersion analysis or the manual method. Adjust to the appropriate averaging time (24 hours for TWA, 15 minutes for STEL or ceiling limits, and annual for a RBAC or RfC).

C. Compare MGLC from dispersion analysis with AAC

(i) If MGLC is less than AAC, proceed with application review, pollutant impact is indicated to be insignificant.

(ii) If MGLC is greater than AAC, request ISC3 or appropriate computer dispersion analysis as in subsection D. of this schedule.

(iii) If both a 24-hour (or annual) AAC and a 15-minute AAC were derived in subsection A., compare both MGLC's with the appropriate AAC's. If either MGLC is greater than the AAC, request ISC3 or appropriate dispersion analysis as in subsection D. of this schedule.

D. Request or perform ISC3 or appropriate computer dispersion analysis for MGLC. Exclude any on-property concentrations, if applicable.

E. Compare MGLC from computer analysis of subsection D. with AAC from subsection A. of this schedule.

(i) If MGLC is less than AAC, proceed with application review, pollutant impact is indicated to be insignificant.

(ii) If MGLC is greater than AAC, notify applicant that review indicates potential adverse toxic air pollutant impact. Reduction in pollutant emission rate, additional controls, and/or increase in stack height may be requested. The applicant may perform their own impact assessment and submit it to the Division for review and consideration.

F. If after notification to applicant of adverse impact [paragraph E.(ii) of this schedule] pollutant emissions will be reduced, controls added, and/or stack height increased, the impact assessment should be repeated, starting with subsection B. of this schedule, to confirm that emissions will have insignificant impact.

2. Multiple Sources/Multiple Pollutants

The permit application reviewer may find that two or more pollutants are emitted simultaneously from a single emission point. There will also be cases where the facility under review contains two or more emission points, each emitting two or more pollutants. If necessary, each pollutant from each emission point may be assessed for toxic impact according to the schedule in section 1. of Part IV. Such a procedure will certainly be time consuming if the facility under review has many emission points emitting many different pollutants. The following abbreviated toxic impact review schemes are recommended to be employed as time saving measures.

A. Single emission point with simultaneous emission of multiple pollutants

(i) Examine toxicity for all pollutants emitted, calculate the acceptable ambient concentration (AAC) as per Part III. for each pollutant, and select the pollutant with the lowest AAC for impact assessment.

(ii) Add the emission rates for all emissions from the single emission point. Use the SCREEN3 computer model with the combined emission rate to determine the maximum ground-level concentration (MGLC) for the pollutant with the lowest AAC, correcting to the appropriate averaging time as per subsection 1.D. of Part II.

(iii) Compare the derived MGLC from (ii) with the AAC for the pollutant selected in (i) above. If the MGLC is less than the AAC, no significant toxic impact is expected for any of the pollutants emitted. If the MGLC is greater than the AAC, proceed as follows.

(iv) Derive the MGLC for each pollutant emitted at the actual emission rates. Note that it is only necessary to run the computer model to determine the MGLC for one of the pollutants. The MGLC for the remaining pollutants may be obtained through a direct ratio of emission rates. The formula is as below:

$$\frac{Q_2}{Q_1}(X_1) = X_2$$

where:

Q_1 = the emission rate of the pollutant previously modeled
Q_2 = the emission rate of a pollutant for which a MGLC is desired
X_1 = the MGLC of the pollutant previously modeled
X_2 = the MGLC for that pollutant

The ratio formula should only be applied between pollutants emitted from the same effective height (stack height plus plume rise).

(v) Compare the MGLC for each pollutant with the respective pollutant AAC and proceed with review of each pollutant as per subsection C. of the schedule of section 1. of Part IV.

B. Multiple emission points all emitting the same specific pollutant

(i) Examine toxicity data for the pollutant and calculate the AAC as per Part III.

(ii) Examine the effective pollutant release height (stack height plus plume rise) for each emission point and select the lowest release height of the emission points.

(iii) Derive the MGLC for the pollutant, correcting to the appropriate averaging time. Use the SCREEN3 computer program with the assumption that the total pollutant emission rate from all emission points is released from a single point at the lowest release height selected in (ii) above. When assuming that all emissions are released from the stack with the lowest release height (stack height plus plume rise) you should <u>not</u> exclude impacts which are located within the plant boundary.

(iv) Compare the derived MGLC with the AAC for the pollutant. If the MGLC is less than the AAC, no significant toxic impact is expected from any emission point. If the MGLC is greater than the AAC, run the SCREEN3 model on each individual stack and add the results together to obtain a total MGLC. If after this step the MGLC is still greater than the AAC, request or perform ISC3 or appropriate computer dispersion analysis to determine the combined MGLC for all emission points.

C. Multiple emission points emitting different pollutants

(i) Examine toxicity data for all pollutants emitted. Calculate the AAC for each pollutant as per Part III. and select the pollutant with the lowest AAC for impact assessment.

(ii) Examine the effective pollutant release height for each emission point and select the lowest release height (stack height plus plume rise) of the emission points.

(iii) Derive the MGLC for the pollutant with the lowest AAC, correcting to the appropriate averaging time. Use the SCREEN3 computer program with the assumptions that the total of all pollutant emission rates from all emission points are released from a single point at the selected lowest release height, and that the total emission rate is composed only of the pollutant with the lowest AAC. When assuming that all emissions are released from the stack with the lowest release height (stack height plus plume rise) you should <u>not</u> exclude impacts which are located within the plant boundary.

(iv) Compare the derived MGLC from (iii) with the AAC for the pollutant selected in (i) above. If the MGLC is less than the AAC, no significant impact is expected for any pollutant from any emission point. If the MGLC is greater than the AAC, proceed as follows.

(v) Derive the MGLC for each pollutant, correcting to the appropriate averaging time, using the assumption that the total emissions of each pollutant from all emission points are released from a single point at the selected lowest release height. The MGLC for each pollutant may be derived, without further modeling, by use of the ratio formula of subparagraph 3.A.(iv) of this Part and the MGLC/emission rate data from subparagraph 3.C.(iii). When assuming that all emissions are released from the stack with the lowest release height you should <u>not</u> exclude impacts which are located within the plant boundary.

(vi) Compare the MGLC for each pollutant with the respective pollutant AAC. For those pollutants with a MGLC less than the AAC, no significant toxic impact is expected. For pollutants which have a MGLC greater than the AAC, run the SCREEN3 model on each individual stack and add the results together to obtain a total MGLC. If after this step the MGLC for one or more pollutants is still greater than the AAC, request or perform ISC3 or appropriate computer dispersion analysis for each emission point emitting such pollutants to determine the MGLC.

D. Additive/synergistic effects from multiple pollutant exposure

(i) When two or more pollutants are known to have the same effect upon the same organ system of the body, the impact of simultaneous exposure to the pollutants are "additive." In these cases, the impact assessment should account for the combined impact of the pollutants as opposed to the independent assessment of each pollutant found in subsections 2.A. and 2.C. of this Part.

The following formula is recommended for use when the effects of simultaneous exposure to two or more pollutants are known to be additive.

$$\frac{MGLC_1}{AAC_1} + \frac{MGLC_2}{AAC_2} + \ldots + \frac{MGLC_n}{AAC_n} \leq 1$$

where $MGLC_{1,\ 2,\ n}$ are the maximum ground-level concentrations of each pollutant and $AAC_{1,2,n}$ are the acceptable ambient concentrations of each pollutant. When the sum of the terms are less than or equal to one, no significant toxic effect is expected. If the sum of the terms is greater than

one, the reviewer should proceed as per subsection D. of the schedule in section 1. using the above formula for further comparison of pollutant MGLC/AAC.

(ii) When two or more pollutants are known to have adverse effects on an organ system of greater magnitude than a simple additive relation, the impact of simultaneous exposure to the pollutants are "synergistic." In cases where documented research indicates synergism, it is recommended that a greater safety factor be used in computing each pollutant's AAC in Part III. of this guideline. The increase in safety factor should be related, as directly as possible, to the indicated increase in potential toxic impact over that which may occur during a simple additive pollutant exposure.

3. Modified Sources

When an air toxics review is being conducted on a modified existing source, the review shall include the same pollutants from the existing equipment as is emitted from the new and modified equipment. If one or more pollutants emitted from a facility cannot pass these guidelines, the Division may approve the application for the construction and operation of the new and modified equipment if the owner or operator either reduces the emissions of those pollutants which cannot pass the guidelines from the existing equipment so that there is no net increase in emissions of each of those pollutants or installs New Source MACT on the new and modified equipment to control those pollutants. The Division reserves the right to set a schedule requiring the entire source to come into compliance with these guidelines.

4. Summary

The impact of toxic air pollutants is assessed by comparing the maximum ground-level pollutant concentrations found by the methods described in Part II. with the acceptable ambient concentrations derived by the methods of Part III. of this guideline. For pollutants for which U.S. EPA has developed a RBAC or Reference Concentration (RfC), an annual AAC is developed. For pollutants without a RBAC or RfC, 24-hour average AAC's are developed. For pollutants with a STEL or ceiling concentration, 15-minute average AAC's are developed. The recommended procedure for comparison is the schedule found in section 1. of Part IV. Guidelines for assessment of potential adverse impact from multiple sources or from simultaneous emission of multiple pollutants are given in section 2. of Part IV.

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Air Contaminants - Permissible Exposure Limits, U.S. Department of Labor, Occupational Safety and Health Administration (OSHA), 29 CFR 1910, subpart Z, as amended, 1995.

This document contains permissible limits (PEL's) in the form of 8-hour time weighted averages (PEL-TWA) and Ceiling Limits (PEL-C) for occupational exposure to toxic materials. Some materials listed under generic names, very few trade names. These are Federal standards subject to routine revision.

Documentation of Threshold Limit Values and Biological Exposure Limits, 5th ed., 1986. American Conference of Governmental and Industrial Hygienists (ACGIH).

This document provides detailed documentation for chemical-specific exposure limits recommended by the ACGIH. Gives the chemical formula, statement on toxicity and hazards, explanation of the basis for selection of the TLV, and references for each substance. Contains listing of known and suspect human carcinogens. Updated yearly.

Integrated Risk Information System (IRIS). 1993. U.S. Environmental Protection Agency, Washington, DC.

IRIS, prepared and maintained by the U.S. Environmental Protection Agency (U.S. EPA), is an electronic data base containing health risk and U.S. EPA regulatory information on specific chemicals. Descriptive and numerical information of chemicals is included in the following categories: oral and inhalation reference doses (RfDs and RfCs) for chronic noncarcinogenic health effects, oral and inhalation slope factors and unit risks for chronic exposures to carcinogens, drinking water health advisories from U.S. EPA's Office of Drinking Water, U.S. EPA regulatory action summaries, and supplementary data on acute health hazards and physical/chemical properties.

Merck Index: An Encyclopedia of Chemicals and Drugs, 10th ed. Martha Windholz, ed. Rahway, New Jersey: Merck and Co., Inc., 1983.

This document gives concise information on over 10,000 chemicals. Includes discussion of isolation, preparation, biosynthesis, physical and biological properties, pharmacological actions, uses and toxicity.

NIOSH/OSHA Occupational Health Guidelines for Chemical Hazards. U.S. Dept. of Health and Human Services/Public Health Service/Center for Disease Control/National Institute for Occupational Safety and Health (NIOSH), U.S. Department of Labor/OSHA. January 1981. DHHS(NIOSH) Publication No. 81-123.

Occupational guidelines on 397 chemicals and metals are compiled in this document. Information on permissible exposure limits, chemical and physical properties, and health hazards is summarized. Recommendations for medical surveillance, respiratory protection, personal protection, and sanitary practices for specific chemicals that are federally regulated are provided. Recommendations are revised according to latest research.

Registry of Toxic Effects of Chemical Substances, 1985-86 Edition. U.S. Department of Health and Human Services, National Institute for Occupational Safety and Health (NIOSH). Washington, D.C.

This document lists prime chemical name substances with their associated toxicity data; includes all substances for which regulatory or consensus group information is cited. This edition replaces and updates the older printed versions of RTECS. May possibly trace trade names to I.U.P.A.C.

Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices, 1993-1994 Edition. American Conference of Governmental Industrial Hygienists (ACGIH).

This document contains Threshold Limit Values (TLV's) in the form of 8-hour time weighted averages (TLV-TWA), 15-minute Short Term Exposure Limits (TLV-STEL) and Ceiling limits (TLV-C) for occupational exposure to toxic materials. Also indicates whether a substance is a known (confirmed) human carcinogen or a suspected human carcinogen. These are recommendations or guidelines and intended for use in the practice of industrial hygiene.

APPENDIX A

BRIGGS' EQUATION FOR ESTIMATION OF PLUME RISE

1.1.4 Plume Rise Formulas

The Briggs plume rise formula equations are discussed below. The description follows Appendix B of the Addendum to the MPTER User's Guide (Chico and Catalano, 1986) for plumes unaffected by building wakes. The distance dependent momentum plume rise equations, as described in (Bowers, et al., 1979), are used to determine if the plume is affected by the wake region for building downwash calculations. These plume rise calculations for wake determination are made assuming no stack-tip downwash for both the Huber-Snyder and the Schulman-Scire methods. When the model executes the building downwash methods of Schulman and Scire, the reduced plume rise suggestions of Schulman and Scire (1980) are used.

1.1.4.1 Stack-tip Downwash

In order to consider stack-tip downwash, modification of the physical stack height is performed following Briggs (1974, p. 4). The modified physical stack height h_s' is found from:

$$h_s' = h_s + 2d_s\left[\frac{v_s}{u_s} - 1.5\right] \qquad \text{for~ v_\{s\}<`1.5`u_\{s\}}$$

or (1-7)

$$h_s' = h_s \qquad \text{for } v_s \geq 1.5\ u_s$$

where h_s is physical stack height (m), v_s is stack gas exit velocity (m/s), and d_s is inside stack top diameter (m). This h_s' is used throughout the remainder of the plume height computation. If stack tip downwash is not considered, $h_s' = h_s$ in the following equations.

1.1.4.2 Buoyancy and Momentum Fluxes

For most plume rise situations, the value of the Briggs buoyancy flux parameter, F_b (m^4/s^3), is needed. The following equation is equivalent to Equation (12), (Briggs, 1975, P. 63):

$$F_b = g v_s d_s^2 \left(\frac{\Delta T}{4T_s}\right) \tag{1-8}$$

where $\Delta T = T_s - T_a$, T_s is stack gas temperature (K), and T_a is ambient air temperature (K).

For determining plume rise due to the momentum of the plume, the momentum flux parameter, F_m (m^4/s^2), is calculated based on the following formula:

$$F_m = v_s^2 d_s^2 \frac{T_a}{4T_s} \tag{1-9}$$

1.1.4.3 Unstable or Neutral - Crossover Between Momentum and Buoyancy

For cases with stack gas temperature greater than or equal to ambient temperature, it must be determined whether the plume rise is dominated by momentum or buoyancy. The crossover temperature difference, $(\Delta T)_c$, is determined by setting Briggs' (1969, p. 59) Equation 5.2 equal to the combination of Briggs' (1971, p. 1031) Equations 6 and 7, and solving for ΔT, as follows:

For $F_b < 55$,

$$(\Delta T)_c = 0.0297\, T_s \frac{v_s^{1/3}}{d_s^{2/3}} \tag{1-10}$$

For $F_b \geq 55$,

$$(\Delta T)_c = 0.00575\, T_s \frac{v_s^{2/3}}{d_s^{1/3}} \tag{1-11}$$

If the difference between the stack gas and ambient temperature, ΔT, exceeds or equals $(\Delta T)_c$, plume rise is assumed to be buoyancy dominated, otherwise plume rise is assumed to be momentum dominated.

1.1.4.4 Unstable or Neutral - Buoyancy Rise

For situations where ΔT exceeds $(\Delta T)_c$ as determined above, buoyancy is assumed to dominate. The distance to final rise, x_f, is determined from the equivalent of Equation (7), (Briggs, 1971, p. 1031), and the distance to final rise is assumed to be 3.5x*, where x* is the distance at which atmospheric turbulence begins to dominate entrainment. The value of x_f is calculated as follows:

for $F_b < 55$:

$$x_f = 49 F_b^{5/8} \tag{1-12}$$

and for $F_b \geq 55$:

$$x_f = 119 F_b^{2/5} \tag{1-13}$$

The final effective plume height, h_c (m), is determined from the equivalent of the combination of Equations (6) and (7) (Briggs, 1971, p. 1031):

for $F_b < 55$:

$$h_e = h_s' + 21.425 \frac{F_b^{3/4}}{u_s} \tag{1-14}$$

and for $F_b \geq 55$:

$$h_e = h_s' + 38.71 \frac{F_b^{3/5}}{u_s} \tag{1-15}$$

1.1.4.5 Unstable or Neutral - Momentum Rise

For situations where the stack gas temperature is less than or equal to the ambient air temperature, the assumption is made that the plume rise is dominated by momentum. If ΔT is less than $(\Delta T)_c$ from equation (1-10) or (1-11), the assumption is also made that the plume rise is dominated by momentum. The plume height is calculated from Equation (5.2) (Briggs, 1969, p.59):

$$h_e = h_s' + 3 d_s \frac{v_s}{u_s} \tag{1-16}$$

Briggs (1969, p.59) suggests that this equation is most applicable when v_s/u_s is greater than 4.

1.1.4.6 Stability Parameter

For stable situations, the stability parameter, s, is calculated from the equation (Briggs, 1971, p. 1031):

$$s = g\frac{\partial\theta/\partial z}{T_a} \tag{1-17}$$

As a default approximation, for stability class E (or 5) $\partial\theta/\partial z$ is taken as 0.035 K/m.

1.1.4.7 Stable - Crossover Between Momentum and Buoyancy

For cases with great stack gas temperature greater than or equal to ambient temperature, it must be determined whether the plume rise is dominated by momentum or buoyancy. The crossover temperature difference, $(\Delta T)_c$, is determined by setting Briggs' (1975, p.96) Equation 59 equal to Briggs' (1969, p. 59) Equation 4.28, and solving for ΔT, as follows:

$$(\Delta T)_c = 0.019582\, T_s v_s \sqrt{S} \tag{1-18}$$

If the difference between stack gas and ambient temperature, ΔT, exceeds or equals $(\Delta T)_c$, plume rise is assumed to be buoyancy dominated, otherwise plume rise is assumed to be momentum dominated.

1.1.4.8 Stable - Buoyancy Rise

For situations where ΔT exceeds $(\Delta T)_c$ as determined above, buoyance is assumed to dominate. The distance to final rise, x_f, is determined by the equivalent of a combination of Equations (48) and (59) in Briggs (1975), p. 96:

$$x_f = 2.0715\ \frac{u_s}{\sqrt{S}} \tag{1-19}$$

The plume height, h_e, is determined by the equivalent of equation (59) (Briggs, 1975, p. 96):

$$h_e = h_s^{/} + 2.6\left(\frac{F_b}{u_s s}\right)^{1/3} \tag{1-20}$$

1.1.4.9 Stable - Momentum Rise

Where the stack gas temperature is less than or equal to the ambient air temperature, the assumption is made that the plume rise is dominated by momentum. If ΔT is less than $(\Delta T)_c$ as determined by Equation (1-18), the assumption is also made that the plume rise is dominated by momentum. The plume height is calculated from Equation 4.28 of Briggs (1969, p. 59):

$$h_e = h_s' + 1.5\left(\frac{F_m}{u_s\sqrt{s}}\right)^{1/3} \tag{1-21}$$

The equation for unstable-neutral momentum rise (1-16) is also evaluated. The lower result of these two equations is used as the resulting plume height.

1.1.4.10 <u>All Conditions - Distance Less Than Distance to Final Rise</u>

Where gradual rise is to be estimated for unstable, neutral, or stable conditions, if the distance downwind from source to receptor, x, is less than the distance to final rise, the equivalent Equation 2 of Briggs (1972, p. 1030) is used to determine plume height:

$$h_e = h_s' + 1.60\left(\frac{F_b^{1/3}x^{2/3}}{u_s}\right) \tag{1-22}$$

This height will be used only for buoyancy dominated conditions; should it exceed the final rise for the appropriate condition, the final rise is substituted instead.

For momentum dominated conditions, the following equations (Bowers, et al., 1979) are used to calculate a distance dependent momentum plume rise:

a) <u>unstable conditions:</u>

$$h_e = h_s + \left(\frac{3F_m x}{\beta_j^2 u_s^2}\right)^{1/3} \tag{1-23}$$

where x is the downwind distance (meters), with a maximum value defined by x_{max} as follows:

$$x_{max} = \frac{4d_s(v_s + 3u_s)^2}{v_s u_s} \qquad \text{for } F_b = 0$$

$$= 49F_b^{5/8} \qquad \text{for } 0 < F_b \le 55\ m^4/s^3 \tag{1-24}$$

$$= 119F_b^{2/5} \qquad \text{for } F_b > 55\ m^4/s^3$$

b) <u>stable conditions:</u>

$$h_e = h_s' + \left[3F_m \frac{\sin(x\sqrt{s}/u_s)}{\beta_j^2 u_s\sqrt{s}}\right]^{1/3} \tag{1-25}$$

where x is the downwind distance (meters), with a maximum value defined by x_{max} as follows:

$$x_{max} = 0.5 \frac{\pi u_s}{\sqrt{s}} \tag{1-26}$$

The jet entrainment coefficient, β_j, is given by,

$$\beta_j = \frac{1}{3} + \frac{u_s}{v_s} \tag{1-27}$$

As with the buoyant gradual rise, if the distance-dependent momentum rise exceeds the final rise for the appropriate condition, then the final rise is substituted instead.

1.1.4.10.1 Calculating the plume height for wake effects determination

The building downwash algorithms in the ICS2 models always require the calculation of a distance dependent momentum plume rise. When building downwash is being simulated, the equations described above are used to calculate a distance dependent momentum plume rise at a distance of two building heights downwind from the leeward edge of the building. However, stack-tip downwash is not used when performing this calculation (i.e. $h_s' = h_s$). This wake plume height is compared to the wake height based on the GEP formula to determine whether the building wake effects apply to the plume for that hour.

The procedures used to account for the effects of building downwash are discussed more fully in Section 1.1.5.3. The plume rise calculations used with the Schulman-Scire algorithm are discussed in section 1.1.4.11.

1.1.4.11 Plume Rise When Schulman and Scire Building Downwash is Selected

The Schulman-Scire downwash algorithms are used by the ISC2 models when the stack height is less than the building height plus one half of the lesser of the building height or width. When these criteria are met, the ISC2 models estimate plume rise during building downwash conditions following the suggestion of Scire and Schulman (1980). The plume rise during building downwash conditions is reduced due to the initial dilution of the plume with ambient air.

The plume rise is estimated as follows. The initial dimensions of the downwashed plume are approximated by a line source of length L_y and depth $2R_o$ where:

$$R_o = \sqrt{2} A \sigma_z \qquad x = 3L_B \tag{1-28}$$

$$L_y = \sqrt{2\pi}\,(\sigma_y - \sigma_z) \qquad x = 3L_B,\ \sigma_y \geq \sigma_z \tag{1-29a}$$

$$L_y = 0 \qquad x = 3L_B,\ \sigma_y < \sigma_z \tag{1-29b}$$

L_B equals the minimum of h_b and h_w, where h_b is the building height and h_w the projected (crosswind) building width. A is a linear decay factor and is discussed in more detail in Section 1.1.5.3.2. If there were no enhancement of σ_y or if the enhanced σ_y is less than the enhanced σ_z, the initial plume would be represented by a circle of radius R_o. The $\sqrt{2}$ factor converts the Gaussian σ_z to an equivalent uniform

circular distribution and $\sqrt{2\pi}$ converts σ_y to an equivalent uniform rectangular distribution. Both σ_y and σ_z are evaluated at $x=3L_B$, and are taken as the larger of the building enhanced sigmas and the sigmas obtained from the curves (see Section 1.1.5.3). The value of σ_z used in the calculation of L_y also includes the linear decay term A.

The rise of a downwashed finite line source was solved in the BLP model (Scire and Schulman, 1980). The neutral distance-dependent rise (Z) is given by:

$$Z^3 + \left(\frac{3L_y}{\pi\beta} + \frac{3R_o}{\beta}\right)Z^2 + \left(\frac{6R_oL_y}{\pi\beta^2} + \frac{3R_o^2}{\beta^2}\right)Z = \frac{3F_bx^2}{2\beta^2u_s^3} + \frac{3F_mx}{\beta_j^2u_s^2} \tag{1-30}$$

The stable distance-dependent rise is calculated by:

$$Z^3 + \left(\frac{3L_y}{\pi\beta} + \frac{3R_o}{\beta}\right)Z^2 + \left(\frac{6R_oL_y}{\pi\beta^2} + \frac{3R_o^2}{\beta^2}\right)Z = \frac{3F_bx^2}{2\beta^2u_s^3} + \frac{3F_m\sin\left(\frac{x\sqrt{s}}{u_s}\right)}{\beta_j^2u_s\sqrt{s}} \tag{1-31a}$$

with a maximum stable buoyant rise given by:

$$Z^3 + \left(\frac{3L_y}{\pi\beta} + \frac{3R_o}{\beta}\right)Z^2 + \left(\frac{6R_oL_y}{\pi\beta^2} + \frac{3R_o^2}{\beta^2}\right)Z = \frac{6F_b}{\beta^2u_ss} \tag{1-31b}$$

where:

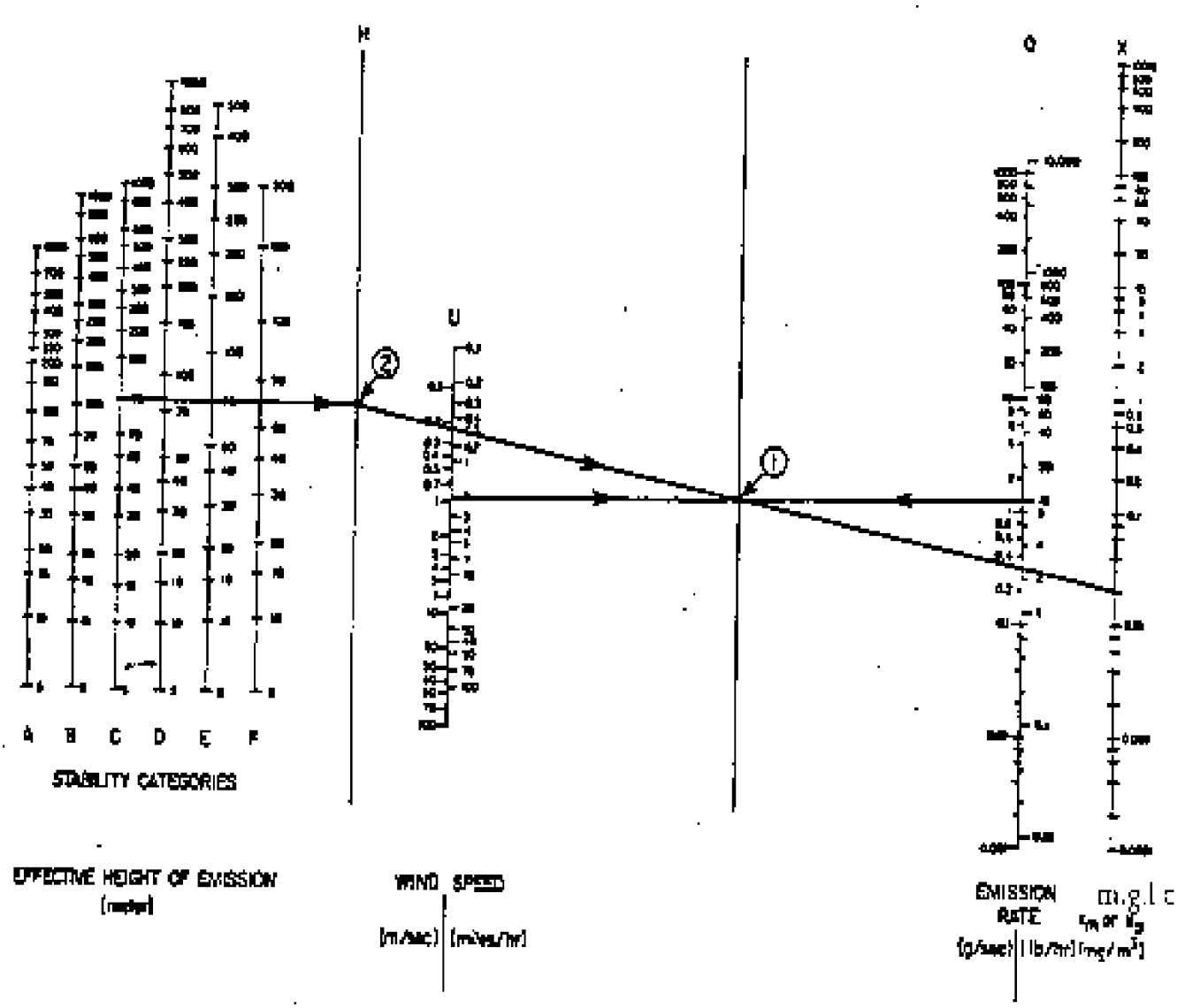
F_b = buoyancy flux term (equation 1-8) (m^4/s^3)
F_m = momentum flux term (equation 1-9) (m^4/s^3)
x = downwind distance (m)
u_s = wind speed at release height (m/s)
v_s = stack exit velocity (m/s)
d_s = stack diameter (m)
β = entrainment coefficient (=0.6)
β_j = jet entrainment coefficient = $1/3+ u_s/v_s$

s = stability parameter $= g\,\dfrac{\partial\theta/\partial z}{T_a}$

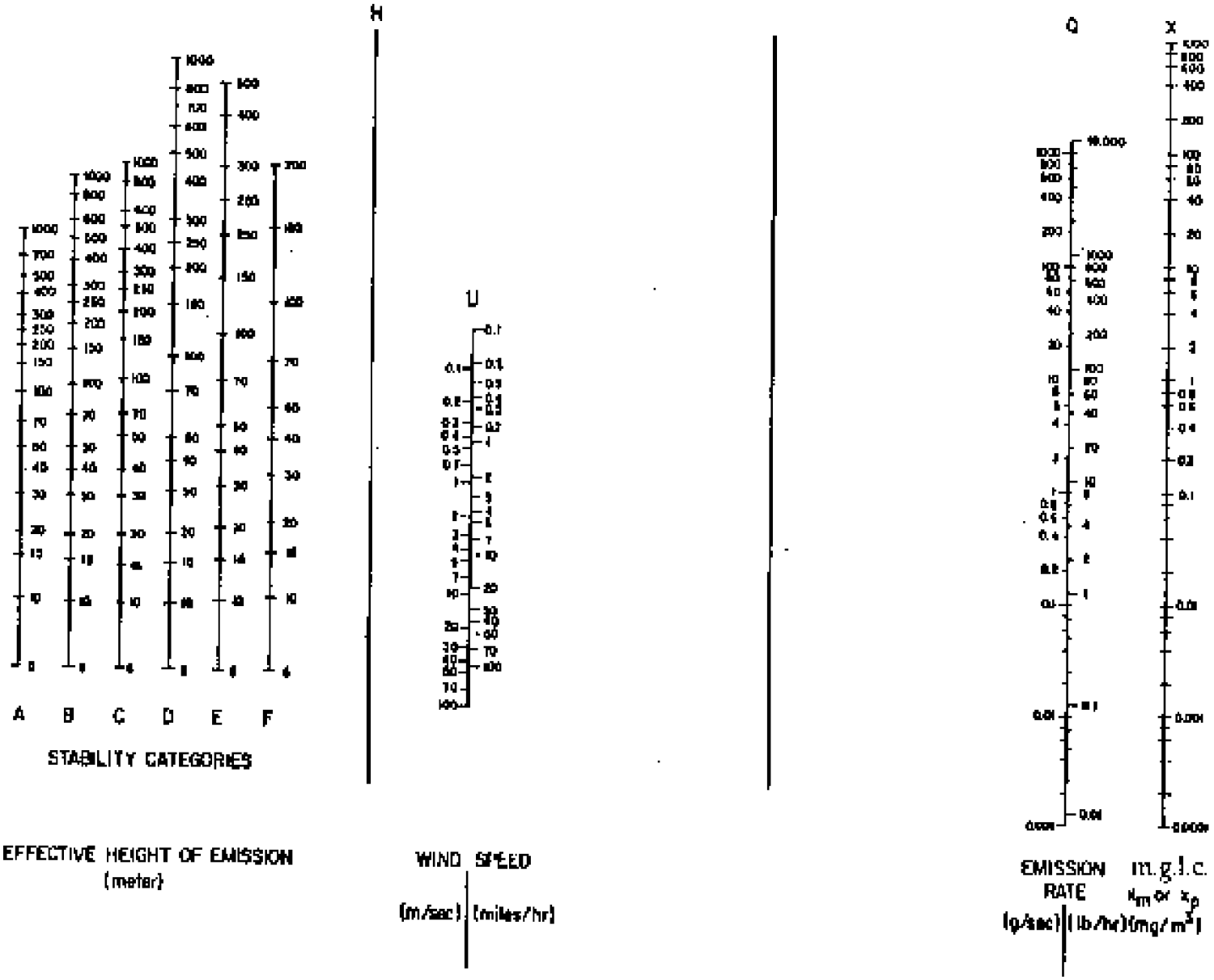
The larger of momentum and buoyancy rise, determined separately by alternately setting F_b or $F_m = 0$ and solving for z, is selected for plume height calculations for Schulman-Scire downwash. In the ISC2 models, Z is determined by solving the cubic equation using Newton's method.

APPENDIX B

NOMOGRAPH FOR MANUAL ESTIMATION OF MAXIMUM POLLUTANT CONCENTRATION



Nomographic example for the calculation of maximum ground level concentration resulting from given stack emission rate

1. Locate effective height on selected stability category scale.
2. Draw line from the effective emission height point perpendicular to tie line H. Note point of intersection.
3. Locate selected wind speed and emission rate on wind speed, emission rate scales.
4. Draw line between wind speed and emission rate points. Note point of intersection with center tie line.
5. Draw line from point 2 on tie line H, through point 1 on the center tie line, to maximum ground level concentration scale (m.g.l.c.). Note maximum ground level concentration.

Nomograph for the Correlation of Stack Emission Rates and Maximum Ground Level Concentrations