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ATMOSPHERIC RELATIVE CONCENTRATIONS FOR CONTROL ROOM RADIOLOGICAL HABITABILITY ASSESSMENTS AT NUCLEAR POWER PLANTS

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A. INTRODUCTION

This guide provides guidance on determining atmospheric relative concentration (χ/Q) values in support of design basis control room radiological habitability assessments at nuclear power plants. This guide describes methods acceptable to the NRC staff for determining χ/Q values that will be used in control room radiological habitability assessments performed in support of applications for licenses[1] and license amendment requests.

In 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," Section 50.34, "Contents of Applications; Technical Information," requires that each applicant for a construction permit or operating license provide an analysis and evaluation of the design and performance of structures, systems, and components of the facility with the objective of assessing the risk to public health and safety resulting from the operation of the facility. Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50 establishes minimum requirements for the principal design criteria for water-cooled nuclear power plants. General Design Criterion 19 (GDC-19), "Control Room," of Appendix A establishes minimum requirements for the facility control room. Included is the requirement that adequate radiation protection be provided to permit access and occupancy of the control room for the duration of accident conditions. Similar criteria are provided in 10 CFR Part 50.67(b)(2)(iii) for plants that use alternative source terms. Atmospheric relative concentrations are significant inputs in assessments performed to demonstrate compliance with these regulations.

Many of the regulatory positions presented in this guide represent substantial changes from procedures previously used to determine atmospheric relative concentrations for assessing the potential control room radiological consequences for a range of postulated accidental releases of radioactive material to the atmosphere. These revised procedures are largely based on the NRC-sponsored computer code, ARCON96 (Ref. 1). This code implements an improved building wake dispersion algorithm; assessment of ground level, building vent, elevated, and diffuse source release modes; use of hour-by-hour meteorological observations; sector averaging; and directional dependence of dispersion conditions. This guide also provides procedures for addressing some aspects of control room χ/Q determinations not currently implemented in the ARCON96 code.

The information collections contained in this draft regulatory guide are covered by the requirements of 10 CFR Part 50, which were approved by the Office of Management and Budget (OMB), approval number 3150-3011. The NRC may not conduct or sponsor, and a person is not required to respond to, a request for information or an information collection requirement unless the requesting document displays a currently valid OMB control number.

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[1] This guide will be useful to applicants for construction permits or operating licenses under Part 50; applicants for design certifications under Part 52, "Early Site Permits; Standard Design Certifications; and Combined Licenses for Nuclear Power Plants"; and applicants for combined licenses under Part 52 who do not reference a standard design certification. See the Implementation section of this guide.

B. DISCUSSION

In licensing proceedings for currently operating nuclear power plants, the applicants and the NRC staff have used various models for determining atmospheric relative concentration values (χ/Q) for control room habitability evaluation. The primary NRC models were those documented in the control room habitability assessment procedure developed by Murphy and Campe (Ref. 2). The Murphy-Campe procedure provided models addressing three different ground-level source-receptor geometries. Elevated releases were not addressed. The first model was a straight-line Gaussian model for the case of a point source and point receptor geometry with a difference in elevation less than 30 percent of the containment building height. This model included a fixed-value building wake correction. The second model was a straight-line Gaussian model appropriate for three geometries: a point source and point receptor with a difference in elevation greater than 30 percent of the containment building height, a diffuse source and point receptor, and a point source and a volume receptor. The third Murphy-Campe model was used for point or diffuse sources when there were alternative receptors. Section 6.4, "Control Room Habitability System," of the Standard Review Plan (Ref. 3) references the Murphy-Campe models.

In the 1980s, the NRC sponsored studies to evaluate the existing (e.g., Murphy-Campe) models against experimental testing in the environment and in wind tunnels and to develop alternative approaches. The results of these studies were published in 1988 in NUREG/CR-5055, "Atmospheric Diffusion for Control Room Habitability Assessments" (Ref. 4). These results indicated that the existing dispersion models did not reliably predict and typically overestimated the concentrations in the vicinity of buildings. NUREG/CR-5055 presented a statistical model that made significantly more reliable predictions in building wakes. Developmental work continued (Ref. 5, 6, 7). A formal peer review was conducted by the NRC in 1994 and the earlier model was revised in response to this peer review and was included in the ARCON95 code. Slight modifications were made to the code and it was re-issued as ARCON96. The code is documented in Revision 1 of NUREG/CR-6331, "Atmospheric Relative Concentrations in Building Wakes" (Ref. 1).

ARCON96 is a general code for assessing atmospheric relative concentrations in building wakes under a wide range of situations. As such, the ARCON96 code provides some user options that are not considered appropriate for use in design basis evaluations for control room habitability assessments. Although the model implemented in ARCON96 was structured to address short-term atmospheric dispersion in typical reactor site building complexes, there may be atmospheric dispersion scenarios and source-receptor geometries for which the model would be inappropriate, e.g., extremely short duration releases, receptor distances shorter than about 10 meters, or control room outside air intakes located close to the base of tall elevated stacks.

This guide provides guidance on the use of ARCON96 for determining atmospheric relative concentrations to be used in design basis evaluations of control room radiological habitability and provides alternative methods for situations in which the modeling in ARCON96 or the application of ARCON96 is considered insufficient. NUREG/CR-6331 (Ref. 1) is a contractor report that provides a user's guide to the ARCON96 code and provides several illustrative examples to facilitate user understanding. Analysts are cautioned that the information in

NUREG/CR-6331 does not constitute a regulatory position and may not be acceptable in a particular licensing proceeding.

Analysts should not assume that the use of the ARCON96 code as described in this guide is acceptable for purposes other than control room radiological habitability assessments. In particular, regulatory positions on atmospheric relative concentrations for toxic gas dispersion are provided in Regulatory Guide 1.78, "Assumptions for Evaluating the Habitability of a Nuclear Power Plant Control Room During a Postulated Hazardous Chemical Release" (Ref. 8).[2] Regulatory positions on atmospheric relative concentrations for offsite accident radiological consequence assessments are provided in Regulatory Guide 1.145, "Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants" (Ref. 9). Regulatory positions on atmospheric relative concentrations for routine effluent release assessments are provided in Regulatory Guide 1.111, "Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors" (Ref. 10). Although this guide does not address toxic gas dispersion, analysts may find that such considerations need to be reflected in the design and operation of control room outside air intakes.

C. REGULATORY POSITION

1. DEFINITIONS

The following definitions are used within the context of this regulatory guide.

95th-percentile χ/Q value: The χ/Q value that is not exceeded by more than 5.0 percent of the χ/Q values generated with the meteorological observations in the data set. Unless otherwise stated, all χ/Q values referred to in this guide are 95th-percentile values.

Control Room: The plant area, defined in the facility licensing basis, in which actions can be taken to operate the plant safely under normal conditions and to maintain the reactor in a safe condition during accident situations. It encompasses the instrumentation and controls necessary for a safe shutdown of the plant and typically includes the critical document reference file, the computer room (if used as an integral part of the emergency response plan), shift supervisor's office, the operator wash room and kitchen, and other critical areas to which frequent personnel access or continuous occupancy may be necessary in the event of an accident.

Control Room Envelope (CRE): The plant area, defined in the facility licensing basis, that in the event of an emergency can be isolated from the plant areas and the environment external to the CRE. This area is served by an emergency ventilation system, with the intent of maintaining the habitability of the control room. This area encompasses the control room, and may encompass

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[2] Revision 1 to Regulatory Guide 1.78 provides for the use of ARCON96 in cases where the dispersion of the released gas is consistent with the Pasquill-Gifford straight-line Gaussian models in ARCON96.

other non-critical areas to which frequent personnel access or continuous occupancy is not necessary in the event of an accident.

Control Room Intake: The location at which the released radioactive material enters the CRE. Includes intentional ventilation system outside air intakes and other locations of significant infiltration into the CRE.

Freestanding Stack: A stack located outside the zone of influence of structures in the vicinity of the stack. (See Regulatory Position C.3.2.2)

Infiltration (or Inleakage): The transport of released radioactive materials into the CRE via interstices in the structures, systems, and components that comprise the CRE. Such a transport is driven by pressure differentials between the CRE and areas external to the CRE.

Slant Path: The shortest line-of-sight distance from the release point to the control room intake, based on the differences in elevation and the horizontal intervening distance; calculated and used as the source-to-receptor distance by ARCON96.

2.   GENERAL CONSIDERATIONS

The May 9, 1997, version of the ARCON96 code as described in Revision 1 of NUREG/CR-6331 (Ref. 1) is an acceptable methodology for assessing control room χ/Q values for use in design basis accident (DBA) radiological analyses, subject to the positions in this guide, unless unusual siting, building arrangement, release characterization, source-receptor configuration, meteorological regimes, or terrain conditions indicate otherwise. These latter situations need to be addressed on a case-by-case basis.

Although the ARCON96 code, when used as described in this guide, can provide an improved basis for determining site-specific χ/Q values, holders of operating licenses may continue to use χ/Q values determined with methodologies previously approved by the NRC staff and documented in the facility's final safety analysis report (FSAR) to the extent that these values are appropriate for the application in which they are being used.[3] Licensees may also continue to use the licensing basis methodology for determining χ/Q values for newly identified source-receptor combinations or re-generating the approved χ/Q values using more recently collected meteorological data sets. The ARCON96 code and the other models addressed in this guide may be used voluntarily, subject to the guidance herein, as a replacement for the existing licensing basis methodology for determining χ/Q values for design basis control room radiological habitability. Since the existing licensing basis methodology remains valid, a licensee may use the ARCON96 code and the other models addressed in this guide on a selective basis, that is, it is not necessary that existing χ/Q values be updated. The NRC staff does expect that the methodologies will be applied consistently in any particular accident assessment.

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[3] If (1) the previously approved values are based on a misapplication of a methodology, (2) calculational errors are identified in the values, or (3) changes are deemed necessary to ensure adequate protection of the health and safety of the public, the NRC staff will pursue necessary corrections with the licensee or applicant.

For each of the source-to-receptor combinations, the 95th percentile χ/Q should be determined. Values for parameters used as input to the χ/Q assessment should be selected consistent with achieving this confidence level. Selection of conservative, bounding source-to-receptor combinations and less detailed site parameters for the χ/Q evaluation may be sufficient to establish compliance with regulatory guidelines.

Control room χ/Q values are generally determined for each of the following averaging periods: 0-8 hours (or 0-2 hours and 2-8 hours), 8-24 hours, 24-96 hours, 96-720 hours. The period of the most adverse release of radioactive materials to the environment should be assumed to occur coincident with the period of most unfavorable atmospheric dispersion. If the 0-2 hour χ/Q is calculated, this value should be used coincident with the limiting portion of the release to the environment. The 2-8 hour χ/Q value is used for the remaining 6 hours of the first 8-hour time period. Part of this 6-hour interval may occur before or after the limiting 2-hour period. The 8-24, 24-96, and 96-720 hour χ/Q values should similarly be used for the remainder of the release duration. For facilities using the traditional TID-14844 (Ref. 11) source term, the 2-hour period will generally coincide with the start of the event. For facilities with design basis analyses that include an alternative source term, the 2-hour period is often the onset of the in-vessel release phase. In any case, the start of this period should be determined as a part of the analyses for each facility.

3.   CALCULATION OF χ/Q USING ARCON96

This section addresses the use of the ARCON96 code for calculating χ/Q values for design basis control room radiological habitability assessments. The ARCON96 code should be obtained and maintained under an appropriate software quality assurance program that complies with the applicable criteria of Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," to 10 CFR Part 50 and applicable industry consensus standards to which the licensee has committed.

3.1   Meteorological Data Input

The meteorological data needed for χ/Q calculations include wind speed, wind direction, and a measure of atmospheric stability. These data should be obtained from an onsite meteorological measurement program based on the guidance of Safety Guide 23, "Onsite Meteorological Programs" (Ref. 12), that includes quality assurance provisions consistent with Appendix B to 10 CFR Part 50. The meteorological data set used in these assessments should represent hourly averages as defined in Safety Guide 23. Data should be representative of the overall site conditions and be free from local effects such as building and cooling tower wakes, brush and vegetation, or terrain. Collected data should be reviewed to identify instrumentation problems and missing or anomalous observations (see Ref. 13). The size of the data set used in the χ/Q assessments should be sufficiently large such that it is representative of long-term meteorological trends at the site. The NRC staff considers 5 years of hourly observations to be representative of long-term trends at most sites. With sufficient justification of its

representativeness, however, the minimum meteorological data set is one complete year (including all four seasons) of hourly observations.

Wind direction should be expressed as the direction from which the wind is blowing (i.e., the upwind direction from the center of the site) referenced from true north.

Atmospheric stability should be determined by the vertical temperature difference (ΔT) measured over the difference in height appropriate for the projected release height (including plume rise as applicable). A table of ΔT values in units of degrees Centigrade per 100 meters ($^\circ$C/100m) versus stability class is given in Safety Guide 23 (Ref. 12). If other well-documented methodologies are used to estimate atmospheric stability (with appropriate justification), the models described in this guide may require modification. A well-documented methodology is one that is substantiated by diffusion data for conditions similar to those at the nuclear power plant site involved.

Appendix A provides information on the structure and content of the meteorological data set and input parameters used by the ARCON96 code.

3.2   Determination of Release Point (Source) Characteristics

A 95th-percentile χ/Q value should be determined for each identified source-receptor combination. However, it may be possible to identify bounding combinations in order to reduce the needed calculational effort. In determining the bounding combinations it will be necessary to consider the distance, direction, release mode, and height of the various release points to the environment in relation to the various control room intakes. Additional parameters, such as those used in establishing plume rise, may need to be considered in determining the bounding combination.

For cases involving two or more release pathways associated with a single release source, a calculated composite value of χ/Q may be considered on a case-by-case basis if the licensee can demonstrate an acceptable modeling approach and justify the conservatism of any assumed weighting factors.

Changes in associated parameters that could occur as a result of differences between normal operation and accident conditions, differences between accidents, differences that occur over the duration of the accident, single failure considerations, and considerations of loss of offsite power, consistent with accident sequences and descriptions, must all be considered in the characterization of the release points.

The ARCON96 code provides options that allow an analyst to model ground-level, elevated stack, and vent-point source releases. In addition, the analyst can model diffuse area sources as a sub mode of the ground-level release type. These modes and limitations on their use are discussed in the positions that follow.

3.2.1 Ground-Level Releases

The ground-level release mode is appropriate for the majority of control room χ/Q assessments. If the release type is ground level, ARCON96 ignores all user inputs related to release velocity and radius. Release height is used to establish the plume slant path.

3.2.2 Elevated (Stack) Releases

The stack release mode is appropriate for releases from a freestanding, vertical, uncapped stack that is outside the directionally dependent zone of influence of adjacent structures. Such a stack should be more than 2-1/2 times the height of the adjacent structures or be located

- more than 5L downwind of the trailing edge of upwind buildings, and

- more than 2L upwind of the leading edge of downwind buildings, and

- more than 0.5L crosswind of the closest edge of crosswind buildings

where L is the lesser of the height or width of the building creating the downwind, upwind, or crosswind wake. Since L will be dependent on wind direction for most building clusters, it will generally be necessary to assess the zone of influence for all directions within the $90°$ wind direction sector centered on the line of sight between the stack and the control room intake. If multiple intakes are involved such that upwind, downwind, and crosswind orientations are confounded, 5L could be used for each orientation. See Figure 1. Plume rise from buoyancy or mechanical jet effects are not calculated by ARCON96. The analyst may determine plume rise and add the amount of rise to the physical height of the stack to obtain an effective plume height as described in Regulatory Position 6 of this guide.[4] Although ARCON96 does not determine plume rise, the input values of stack flow, radius, and vertical velocity are used by ARCON96 to assess downwash and to estimate a limiting χ/Q value.

If the control room intake is located close to the base of a tall stack, the elevated release model in ARCON96 generates negligibly low χ/Q values. Although perhaps numerically correct, these model results may not be sufficiently conservative for a design basis assessment since the model does not adequately address meteorological conditions that could result in higher χ/Q values. Although the staff has previously suggested that licensees model fumigation as a mechanism to address this situation, the fumigation model did not appear to adequately estimate the effluent concentrations at the bases of industrial stacks. Concentrations greater than those predicted by ARCON96 could result from diurnal wind direction changes, meander, or stagnation. Therefore, the following procedure should be used to assess whether a particular stack-intake configuration is subject to this concern and to determine the appropriate χ/Q values.

In addition to running ARCON96 to determine the elevated stack χ/Q values for the control room assessment, the analyst should calculate the maximum elevated stack χ/Q value (non-fumigation) using the methodology of Regulatory Guide 1.145 (Ref. 9) to determine the maximum χ/Q value at ground level for the 0-2 hour interval and for the 24-96 and 96-720 hour

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[4] The plume rise may not be added to the physical height of the stack for the purpose of meeting the 2-1/2 times height criterion.

intervals. The NRC-sponsored code, PAVAN (Ref. 14), is acceptable to the staff for this assessment. For this assessment, the input parameters should be adjusted such that the effective release height is measured from the elevation of the control room outside air intake rather than plant grade. The same release point characterization and meteorological data sets used in ARCON96 should be used to determine the χ/Q values for several distances in each wind direction sector with the objective of identifying the maximum χ/Q value. Figure A.4 of Reference 15 may be useful in this regard. The maximum χ/Q value obtained for the 0-2 hour interval should be compared to the corresponding χ/Q value generated by ARCON96 and the higher value used in habitability assessments. The χ/Q values generated by ARCON96 for the 2-8 and the 8-24 hour intervals may be used without adjustment.

For the 24-96 hour and 96-720 hour intervals, the following expressions may be used to determine the effective χ/Q. This determinstic approach assumes that the stack plume reverses direction for 1 hour of each day for the duration of the event. The plume is assumed to fold over itself such that the ground level concentration is at its maximum value at the control room intake.

$$\left(\frac{\chi}{Q}\right)_{24\to96\,hr} = \frac{1\cdot\left(\frac{\chi}{Q}\right)^{PAVAN}_{24\to96\,hr} + 23\cdot\left(\frac{\chi}{Q}\right)^{ARCON96}_{24\to96\,hr}}{24} \tag{1}$$

$$\left(\frac{\chi}{Q}\right)_{96\to720\,hr} = \frac{1\cdot\left(\frac{\chi}{Q}\right)^{PAVAN}_{96\to720\,hr} + 23\cdot\left(\frac{\chi}{Q}\right)^{ARCON96}_{96\to720\,hr}}{24} \tag{2}$$

3.2.3 Vent Releases

The ARCON96 calculation of vent releases includes an algorithm to model mixed-mode releases as described in Regulatory Guide 1.111 (Ref. 10), which addresses χ/Q values used in the assessment of routine effluent releases. The development of this algorithm was based in part on limited field experiments. Given the limited experiment set, the results obtained with this algorithm may not be sufficiently conservative for accident evaluations. For this reason, the vent release mode should not be used in design basis assessments. This position is consistent with the guidance of Regulatory Guide 1.145 (Ref. 9) for offsite χ/Q values. These releases should be treated as a ground level release (Section 3.2.1) or as an elevated release (Section 3.2.2).

3.2.4 Diffuse Area Sources

The diffusion models in ARCON96 are based on point-source formulations. However, some release sources may be better characterized as area sources. Examples of possible area sources are postulated releases from the surface of a reactor or a secondary containment building. Typical assessments for loss-of-coolant accidents (LOCAs) have conservatively assumed that the containment structure could leak anywhere on the exposed surface. As such, these assessments typically used the shortest distance between the building surface and the control room intake and

have treated the building as a point source. This approach may be unnecessarily conservative. A more reasonable approach, while still maintaining adequate conservatism, would be to model the building surface as a vertical planar area source. This approach is not intended to address dispersion resulting from building-induced turbulence. Treatment of a release as a diffuse source will be acceptable for design basis calculations if the guidance herein is followed. The staff may consider deviations from this guidance on a case-by-case basis.

3.2.4.1. Diffuse source modeling should be used only for those situations in which the activity being released is homogeneously distributed throughout the building and when the assumed release rate from the building surface would be reasonably constant over the surface of the building. For example, steam releases within a turbine building with roof ventilators or louvered walls would generally not be suitable for modeling as a diffuse source. (See Regulatory Positions 3.2.4.7 and 3.2.4.8.)

3.2.4.2. Since leakage is more likely to occur at a penetration, analysts must consider the potential impact of building penetrations exposed to the environment[5] within this modeled area. If the penetration release would be more limiting, the diffuse area source model should not be used. Releases from personnel air locks and equipment hatches exposed to the environment, or containment purge releases prior to containment isolation, may need to be treated differently. It may be necessary to consider several cases to ensure that the χ/Q value for the most limiting location is identified.

3.2.4.3. The total release rate (e.g., $Ci \cdot s^{-1}$) from the building atmosphere is to be used in conjunction with the diffuse area source χ/Q in assessments. This release rate is assumed to be equally distributed over the entire diffuse source area from which the radioactivity release can enter the environment. For freestanding containments, this would be the entire periphery above grade or above a building that surrounds the lower elevations of the containment. When a licensee can justify assuming collection of a portion of the release from the containment within the surrounding building, the total release from the containment may be apportioned between the exposed and enclosed building surfaces. Similarly, if the building atmosphere release is modeled through more than one simultaneous pathway (e.g., drywell leakage and main steam safety valve leakage in a BWR), only that portion of the total release released through the building surface should be used with the diffuse area χ/Q. The release rate should not be averaged or otherwise apportioned over the surface area of the building. For example, reducing the release rate by 50 percent because only 50 percent of the surface faces the control room intake would be inappropriate.

3.2.4.4. ARCON96 uses two initial diffusion coefficients entered by the user to represent the area source. There are insufficient field measurements to mechanistically model these initial diffusion coefficients. The following deterministic equations should be used in the absence of site-specific empirical data.[6]

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[5] Penetrations that are enclosed within safety-related structures need not be considered in this evaluation if the release would be captured and released via a plant ventilation system, as ventilation system releases should have already been addressed as a separate release point.

[6] See Regulatory Position 7 regarding the use of site-specific empirical measurements.

$$\sigma_{Y_o} = \frac{\text{Width}_{\text{area source}}}{6} \tag{3}$$

$$\sigma_{Z_o} = \frac{\text{Height}_{\text{area source}}}{6} \tag{4}$$

3.2.4.5. The height and width of the area source (e.g., the building surface) are taken as the maximum vertical and horizontal dimensions of the above-grade building cross-sectional area perpendicular to the line of sight from the building center to the control room intake (see Figure 2). These dimensions are projected onto a vertical plane perpendicular to the line of sight and located at the closest point on the building surface to the control room intake. The release height is set at the vertical center of the projected plane. The source-to-receptor distance (slant path) is measured from this point to the control room intake.

3.2.4.6. Intentional releases from a secondary containment (e.g., standby gas treatment systems (SGTS) at BWR reactors) or annulus ventilation systems in dual containment structures should be treated as a ground-level release or an elevated stack release, as appropriate. The diffuse area source model may be appropriate for time intervals for which the secondary containment or annulus ventilation system is not capable of maintaining the requisite negative pressure differential specified in technical specifications or in the FSAR. Secondary containment bypass leakage (i.e., leakage from the primary containment that bypasses the secondary containment and is not collected by the SGTS) should be treated as a ground-level release or an elevated stack release, as appropriate.

3.2.4.7. A second possible application of the diffuse area source model is determining a χ/Q value for multiple (i.e., 3 or more) roof vents. This treatment would be appropriate for configurations in which (1) the vents are in a close arrangement, (2) no individual vent is significantly[7] closer to the control room intake than the center of the area source, (3) the release rate from each vent is approximately the same, and (4) no credit is taken for plume rise. The distance to the receptor is measured from the closest point on the perimeter of the assumed area source. For assumed areas that are not circular, the area width is measured perpendicular to the line of sight from the center of the assumed source to the control room intake. The initial diffusion coefficient σ_{Y_o} is found by Equation 3; σ_{Z_o} is assumed to be 0.0.

3.2.4.8. A third possible application of the diffuse area source model is determining a χ/Q value for large louvered panels or large openings (e.g., railway doors on BWR Mark I plants) on vertical walls. This treatment would be appropriate for a louvered panel or opening when (1) the release rate from the building interior is essentially equally dispersed over the entire surface of the panel or opening and (2) assumptions of mixing, dilution, and transport within the building necessary to meet condition 1 are supported by the interior building arrangement. The staff has traditionally not allowed credit for mixing and holdup in turbine buildings because of the buoyant

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[7] The degree of significance will depend on the radius or width of the assumed area and the proximity of the vent cluster to the control room intake. As the radius decreases or the distance from the cluster to the control room intake increases, the less significance the position of any one vent has.

nature of steam releases and the typical presence of high volume roof exhaust ventilators. The distance to the receptor and the release height is measured from the center of the louvered panel or opening. Initial diffusion coefficients are found using Equations 3 and 4 assuming the width and height is that of the panel or opening rather than that of the building. If the area source and the intake are on the same building surface such that wind flows along the building surface would transport the release to the intake, the initial dispersion coefficient will need to be adjusted. If the included angle between the source-receptor line of sight and the vertical axis of the assumed source is less than 45 degrees, σ_{Y_o} should be set to 0.0. If the included angle between the source-receptor line of sight and the horizontal axis of the assumed source is less than 45 degrees, σ_{Z_o} should be set to 0.0.

3.3   Determination of Control Room Intakes (Receptors)

This section of the guide provides guidance to the meteorological analyst in applying models for determining χ/Q values that are appropriate for the as-built configuration of control room intakes. Radioactive materials released during an accident can enter the control room envelope via several potential pathways. These pathways may be intentional (e.g., ventilation system outside air intakes) and unintentional infiltration paths (e.g., doorways, envelope penetrations, leakage in ventilation system components). The applicable pathways will vary from site to site depending on the arrangement of the control room envelope in relation to other site buildings, the pressure differentials between these buildings and the control room, the configuration of control room ventilation systems, and the classification of the control room dose control (e.g., zone isolation with filtered pressurization, zone isolation with no pressurization). It may be necessary to determine χ/Q values for each potential pathway. However, the selection of one or more bounding intakes for the χ/Q evaluation may be sufficient to establish compliance with regulatory guidelines.

3.3.1   Ventilation System Outside Air Intakes
All control room ventilation systems draw makeup air from the environment during normal operations and many draw air from the environment for the purpose of supplying filtered pressurization air. The configuration of these systems may change between normal and emergency modes. In some configurations, normal ventilation outside air intakes isolate and different intakes open to supply pressurization air. Some intake dampers may have failure modes related to loss of ac power or single failures. These considerations should be evaluated in identifying the control room outside air intakes for which χ/Q values should be calculated.

3.3.2   Dual Ventilation Outside Air Intakes
This section applies to control room ventilation system configurations that have two outside air intakes, each of which meets applicable design criteria of an engineered safeguards feature (ESF), including single-failure criterion, missile protection, seismic criteria, and operability under loss-of-offsite AC power conditions. Operability requirements should be provided in technical specifications. The outside air intakes should be located with the intent of providing a low contamination intake regardless of wind direction. The assurance of a low contamination outside air intake depends on release point configuration, building wake effects, terrain, and the possibility of wind stagnation or wind direction reversals. The two intakes should not be within the same wind direction window, defined as a wedge centered on the line of sight between the

source and the receptor with the vertex located on the release point. If ARCON96 is used, the wedge angle is 90° (i.e., 45 degrees on either side of the line of sight). If the methods of Regulatory Position 4 are used, the size of the wedge is as given in Table 2. Figure 3 illustrates four examples of the interplay between control room intakes, release points, and wind direction windows. In addition, the analyst should consider χ/Q values for infiltration pathways as discussed in Regulatory Position 3.3.3.

The methods of this regulatory position involve identification of the limiting and favorable intakes with regard to their χ/Q value. Because of the interplay of building wake, plume rise, wind direction frequency, intake flow rate, and other parameters, it may not be possible to identify the limiting or favorable intake by observation. In these situations, χ/Q values should be calculated for each release point-intake combination and the limiting and favorable intakes identified on the basis of these values.

3.3.2.1. If both of the dual intakes are located within the same wind direction window, both intakes could be contaminated (See Figure 3(a)). In this case, the χ/Q values for each air intake should be calculated using ARCON96 as described in other sections of this guide and an effective χ/Q value calculated. Equation 5a should be used if the intake flow rates are equal. If the intake flow rates are not equal, but the imbalance does not shift between intakes, Equation 5b should be used. If the flow rate imbalance can shift between intakes, Equation 5c should be used. This calculation is repeated for each averaging time interval.

$$\overline{\chi/Q} = \frac{1}{2}\left[(\chi/Q)_1 + (\chi/Q)_2\right] \tag{5a}$$

$$\overline{\chi/Q} = \frac{F_1 \cdot (\chi/Q)_1 + F_2 \cdot (\chi/Q)_2}{F_1 + F_2} \tag{5b}$$

$$\overline{\chi/Q} = \frac{\max(F_1,F_2)\cdot\max\left[(\chi/Q)_1,(\chi/Q)_2\right]+\min(F_1,F_2)\cdot\min\left[(\chi/Q)_1,(\chi/Q)_2\right]}{F_1 + F_2} \tag{5c}$$

Where:
$$\overline{\chi/Q} \quad = \quad \text{Effective } \chi/Q, \text{ s·m}^{-3}$$
$$(\chi/Q)_1, (\chi/Q)_2 \quad = \quad \chi/Q \text{ value for outside air intakes 1 and 2, s·m}^{-3}$$
$$F_1, F_2 \quad = \quad \text{Flow rate for outside air intakes 1 and 2, cfm}$$

3.3.2.2. If the dual outside air intakes are not in the same wind direction window but cannot be isolated by design, the χ/Q values for the limiting outside air intake should be calculated for each time interval as described elsewhere in this guide. Equation 6a should be used if the intake flow rates are equal. If the intake flow rates are not equal, but the imbalance does not shift between intakes, Equation 6b should be used. If the flow rate imbalance can shift between intakes, Equation 6c should be used.

$$\overline{\chi/Q} = \frac{1}{2}\max\left[(\chi/Q)_1,(\chi/Q)_2\right] \tag{6a}$$

$$\overline{\chi/Q} = \frac{\max\left[F_1 \cdot (\chi/Q)_1, F_2 \cdot (\chi/Q)_2\right]}{F_1 + F_2} \qquad (6b)$$

$$\overline{\chi/Q} = \frac{\max(F_1, F_2) \cdot \max\left[(\chi/Q)_1, (\chi/Q)_2\right]}{F_1 + F_2} \qquad (6c)$$

3.3.2.3. If the ventilation system design allows the operator to manually select the least contaminated outside air intake as a source of outside air makeup and close the other intake, the χ/Q values for each of the outside air intakes should be calculated for each time interval as described elsewhere in this guide. The χ/Q value for the limiting intake should be used for the time interval prior to intake isolation. This χ/Q value may be reduced by a factor of 2 to account for dilution by the flow from the other intake (see Equation 6a).[8] The χ/Q values for the favorable intake are used for the subsequent time intervals. The χ/Q values for the favorable intake may be reduced by a factor of 4 to account for the dual inlet and the expectation that the operator will make the proper intake selection. This protocol should be used only if the dual intakes are in different wind direction windows and if there are redundant, ESF-grade radiation monitors within each intake, with control room indication and alarm, to monitor the intakes. The requisite steps to select the least contaminated outside air intake, and provisions for monitoring to ensure the least contaminated intake is in use throughout the event, should be addressed in procedures and in operator training.

A conservative delay time should be assumed for the operator to complete the necessary actions. This delay period should consider: (1) the time for the operator to recognize the radiation monitor alarm and determine its validity (as provided for in the alarm response procedure), (2) delays associated with other accident response actions competing for the operator's attention, (3) the time needed to complete the actions, and (4) diesel generator sequencing time, if applicable. If actions are required outside the control room, delays associated with transit to the local control stations (including those delays caused by worker radiological protection controls associated with accident dose rates), and the availability of personnel should be considered.

3.3.2.4. If the ventilation system design provides for automatic selection of the least contaminated outside air intake, the χ/Q values for the favorable intake should be calculated for each time interval as described elsewhere in this guide. The χ/Q values may be reduced by a factor of 10 to account for the ability to automatically select a "clean" intake. This protocol should be used only if the dual intakes are in different wind direction windows, there are redundant ESF-grade radiation monitors within each intake, and an ESF-grade control logic and actuation circuitry is provided for the automatic selection of a clean intake throughout the event.

3.3.3 Infiltration Pathways

Infiltration of contaminated air to a control room can be minimized by proper design and maintenance of the control room envelope (CRE). However, infiltration is always a possibility and the location and significance of these leakage pathways may warrant determination of χ/Q values. An unfiltered inleakage path of 100 cfm can admit the same quantity of radioactive material as a pressurization air intake having a flow of 2000 cfm through a 95 percent efficient

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[8] The adjustment protocol and the numeric factors of this section are deterministic in nature and are expected to be conservative for most sites. Different factors may be considered on a case-by-case basis with sufficient justification.

filter. The situation can be further compounded if the χ/Q for the unfiltered pathway is more limiting than that for the control room outside air intake.

The infiltration paths actually applicable to a particular facility will be identified via inleakage testing or CRE inspections and surveillances. Refer to Table H-1, "Determination of Vulnerability Suspectability," of NEI 99-03, "Control Room Habitability Guidance" (Ref. 16), for further guidance on infiltration pathways.

A 95th-percentile χ/Q value should be determined for each time interval for any infiltration path that could result in a significant intake of contaminated air into the CRE. Because of the interplay of source-to-receptor distance and direction, infiltration path flow rate, whether the path is filtered or unfiltered, and other considerations, it may not be possible to identify the potential impact of an infiltration path by observation. In these situations, χ/Q values should be calculated for each pathway and the limiting χ/Q value(s) identified. If there is sufficient margin available, it may be possible to calculate χ/Q values assuming the shortest distance between the release point and any identified point of infiltration on the outside of the CRE.

3.4   Determination of Source-Receptor Distances and Directions

When the combinations of release points and intakes have been identified, the direction and distance between the release point and the intake should be determined. Wind direction data are recorded as the direction from which the wind blows (e.g., a north wind blows from the north, a wind blowing out of the west is recorded with a direction of 270 degrees). The direction input to ARCON96 is the wind direction that would carry the plume from the release point to the intake.[9] For example, an analyst standing at the intake facing west to the release point, would enter 270 degrees; an analyst facing north, would enter 360 degrees, etc.

The source-to-receptor distance is the shortest horizontal distance between the release point and the intake. ARCON96 will use this distance and the elevations of the source and receptor to calculate the slant path. For an area source such as building surface, the shortest horizontal distance from the building surface to the control room intake is used as the source-to-receptor distance. For releases within building complexes, the shortest horizontal distance between the release point and the intake could be through intervening buildings. In these cases, it is acceptable to take the length of the shortest path (e.g., "taut string length") around or over the intervening building as the source-to-receptor distance. If the distance to the receptor is less than about 10 meters, the ARCON96 code and the procedures in Regulatory Position 4 should not be used to assess χ/Q values. These situations will need to be addressed on a case-by-case basis.

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[9] The site meteorological tower wind direction sensors are generally calibrated with reference to true north (360 degrees). Analysts should use caution in measuring directions on site engineering drawings since these drawings typically incorporate a plant grid and a plant "north" that may not align with true north. The source-to-receptor directions input to ARCON96 must use the same north reference as the wind direction observations.

4.   ALTERNATIVE PROCEDURES FOR GROUND-LEVEL RELEASES

This regulatory position addresses alternative methods for determining χ/Q values for control room radiological habitability assessments. The methods in Regulatory Positions 4.1 to 4.3 are based on Murphy-Campe (Ref. 2) and the Standard Review Plan Chapter 6.4 (Ref. 3).

4.1   Point Source-Point Receptor

The 0-8 hour 95th-percentile[10] χ/Q value for a single point source on the surface of the containment or other building and a single point receptor with a difference in elevation less than 30 percent of the building height may be estimated using Equation 7.

$$\frac{\chi}{Q} = \frac{1}{3\pi U \sigma_y \sigma_z} \tag{7}$$

Where:

χ/Q = Relative concentration at plume centerline for time interval 0-8 hours, $s \cdot m^{-3}$

3 = Wake factor

U = Wind speed at 10 meters, $m \cdot s^{-1}$

σ_y, σ_z = Standard deviation, in meters, of the gas concentration in the horizontal and vertical cross wind directions evaluated at distance x and by stability class

4.2   Diffuse Source-Point Receptor

Equation 8 may be used when the activity is assumed to leak from many points on the surface of a building such as the containment in conjunction with a single point receptor. This equation is also appropriate for point source-point receptors where the difference in elevation between the source and the receptor is greater than 30 percent of the height of the upwind building, typically the containment, which creates the most significant building wake impact. The equation is also applicable to a point source and volume receptor (e.g., an isolated control room with infiltration occurring at many locations).

$$\frac{\chi}{Q} = \left[U \left(\pi \sigma_y \sigma_z + \frac{A}{K+2} \right) \right]^{-1} \tag{8}$$

Where:

χ/Q = Relative concentration at plume centerline for time interval 0-8 hours, $s \cdot m^{-3}$

U = Wind speed at 10 meters, $m \cdot s^{-1}$

σ_y, σ_z = Standard deviation, in meters, of the gas concentration in the horizontal and vertical cross wind directions evaluated at distance x and by stability class

K = $\dfrac{3}{(s/d)^{1.4}}$

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[10] The Murphy-Campe document identified this as the 5th-percentile χ/Q value.

$\quad$ s $\quad$ = $\quad$ Shortest distance between building surface and receptor location, m

$\quad$ d $\quad$ = $\quad$ Diameter or width of building, m

$\quad$ A $\quad$ = $\quad$ Cross-section area of building, m^2

$\quad\quad$ The reference to "building" in the definitions of s, d, and A is to the diffuse source (e.g., containment). If the equation is used with a point source, the reference is to the building that has the greatest impact on the building wake. The values of the parameters σ_y, σ_z and U should be determined on the basis of the values of the site meteorological data. Some early analyses may have been based on generic meteorology conditions (e.g., F stability with wind speeds of 1.0 m·s^{-1}). If these early analyses are to be updated, the staff recommends that the ARCON96 code be used. If the ARCON96 code is not used, site-specific hourly meteorological data should be used to determine the 95th-percentile χ/Q value. Figures 4 and 5 provide sigma values by stability category for distances greater than 10 meters. The data on these graphs should not be extrapolated for distances less than 10 meters.

4.3 $\quad$ Point or Diffuse Source with Two Alternative Receptors

$\quad\quad$ Equations 7 and 8 of this guide may be used in conjunction with the procedures in Regulatory Position 3.3.2 to determine χ/Q values for control room designs having two or more control room outside air intakes, each of which meets the requirements of an engineered safety feature (ESF) including, as applicable, single-failure criteria for active components, seismic criteria, and missile criteria. If Equation 8 of this guide is used, the parameter K should be set to 0.0. In a change from previous practice, the staff no longer finds Equation 7 of Reference 2 to be acceptable for use in new applications.

4.4 $\quad$ Determination of χ/Q Values for Other Time Intervals

$\quad\quad$ Equations 7 and 8 are used to determine χ/Q values for the first time interval of 0-8 hours. The χ/Q values for other time intervals are obtained by adjusting for long-term meteorological averaging of wind speed and wind direction.[11] This is accomplished by multiplying the 0-8 hour time interval χ/Q value by a correction factor for wind speed and a correction factor for wind direction.

4.4.1 $\quad$ χ/Q Correction for Wind Speed Averaging
$\quad\quad$ This correction is defined as the ratio of the wind speed used to determine the 0-8 hour χ/Q value to the wind speed appropriate for each of the other time intervals. Column 2 of Table 1 tabulates the wind speed percentiles that correspond to each of these intervals. The hourly data should be arranged in order of increasing wind speed and the wind speed percentiles determined (i.e., the lowest wind speeds associated with the lowest percentiles). Include only the wind speed data associated with wind directions from sectors that result in receptor contamination. Table 2 tabulates the size of the minimum wind direction window to be used. From this ranking, identify the wind speed value for each interval that is not exceeded more than the stated percentage of the time. Divide this wind speed value into the 5th-percentile wind speed used to determine the 0-8 hour χ/Q to obtain the χ/Q correction factor for wind speed. The values shown in Column 1 of Table 1 are representative correction factors that may be used if hourly observation meteorological data are not available.

Table 1

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[11] Previous guidance also provided for including a factor to account for personnel occupancy factors. Since typical radiological analysis codes provide the capability to enter these factors separately, the staff recommends that the factors not be included in the χ/Q value to avoid inadvertent double crediting.

χ/Q Correction for Wind Speed Averaging

Time Interval	Column 1 Representative χ/Q Factors	Column 2 Corresponding Wind Speed Percentile
0-8 hours	1.0	5
8-24 hours	0.67	10
1-4 days	0.50	20
4-30 days	0.33	40

Table 2
Wind Direction Sectors

s/d Ratio	Minimum Window[12]
>2.5	68°
1.25 - 2.5	90°
0.8 – 1.25	113°
0.6 – 0.8	135°
0.5 – 0.6	158°
0.35 – 0.5	180°
<0.35	225°

The s/d is defined as:

$$\frac{s}{d} = \frac{\text{Shortest distance between building surface and receptor location, m}}{\text{Diameter or Width of building, m}} \tag{9}$$

The reference to "building" in Equation 9 is to the diffuse source (e.g., containment). If the equation is used with a point source, the reference is to the building that has the greatest impact on the building wake.

4.4.2 χ/Q Correction for Wind Direction Averaging

The average wind direction frequency F is obtained by summing the annual average wind direction frequencies within the minimum window. Table 2 tabulates the size of the minimum wind direction window to be used. Column 2 of Table 3 is used to determine the χ/Q correction factor for wind direction for each time interval. Column 1 is used when F has not been determined.

Table 3
Wind Direction Averaging Correction

	Column 1 Representative	Column 2 Equations for

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[12] Centered on the source-to-receptor direction.

Time Interval	χ/Q Factors	χ/Q Factors
0-8 hours	1.0	1.0
8-24 hours	0.88	0.75 + F/4
1-4 days	0.75	0.50 + F/2
4-30 days	0.5	F

5.   INSTANTANEOUS PUFF RELEASES

The alternative method in this section may be used to model the release to the environment as an instantaneous puff release. One hundred percent of the radionuclides must be released directly to the environment over a period no longer than about 1 minute for a release to qualify as a puff release. Releases to enclosed buildings, intermittent releases that occur over a period longer than about 1 minute (e.g., releases from relief valves, atmospheric dumps), and releases that occur over a period longer than about 1 minute should be treated as continuous point source releases. The diffusion equation for an instantaneous puff ground level release, with no puff rise and no crosswind offset (i.e., center of puff is assumed to pass over control room intake), integrated over the duration of the puff passage is:

$$\frac{\chi}{Q}(x,u,k,h,) = \frac{\int_0^T \frac{2}{(\sigma_z^2(x,k)+\sigma_I^2)^{1/2}(2\pi)^{3/2}(\sigma_{x,y}^2(x,k)+\sigma_I^2)} \cdot \exp\left[-\frac{1}{2}\left(\frac{(x-u\cdot t)^2}{(\sigma_{x,y}^2(x,k)+\sigma_I^2)} + \frac{h^2}{(\sigma_z^2(x,k)+\sigma_I^2)}\right)\right] \cdot F(t)\, dt}{\int_0^T F(t)dt}$$

(10)

Where:

$\frac{\chi}{Q}(x,u,k,h)$ = Effective puff relative concentration, $s\cdot m^{-3}$

χ = Integrated concentration at control room intake, $Ci\cdot m^{-3}\cdot s^{-1}$

Q_i = Release quantity, for nuclide i, Ci

x = Release point to receptor distance, m

u = Wind speed, m/sec. Assume $1.0\ m\cdot s^{-1}$

k = Stability Class. Assume F.

h = Difference in elevation between the physical release point and the control room intake, m. If the control room intakes is at a higher elevation than the release point and the puff is buoyant, assume h = 0.

T = Time for trailing edge of puff to pass control room intake, sec.

= $\dfrac{x + 3\cdot\left[\sigma_{x,y}(x,k)+\sigma_I\right]}{u}$

F = Control room total intake flow rate, cfm. (If the control room intake flow rate is constant over the period 0 to T seconds, the F(t) terms can be omitted from Equation 10.)

$$\sigma_{x,y}(x,k) \quad = \quad \text{Standard deviation, m, of the puff in the horizontal along the wind direction and cross-wind directions at the receptor location. Use Figure 4 with the distance x and stability class k to determine } \sigma_{x,y} \text{ at the receptor, e.g., } \sigma_{x,y} = \sigma_y.$$

$$\sigma_z(x,k) \quad = \quad \text{Standard deviation, m, of the puff in the vertical cross-wind direction at the receptor location. Use Figure 5 with the distance x and stability class k to determine } \sigma_z \text{ at the receptor.}$$

$$\sigma_I \quad = \quad \text{Initial standard deviation, m}$$

$$= \quad \left[\frac{2 \cdot V}{(2\pi)^{3/2}} \right]^{1/3}$$

$$V \quad = \quad \text{Initial puff volume (expanded to standard atmospheric conditions), } m^3 \text{ (The puff dimensions that would exist when the puff is at the control room intake are assumed to exist during the entire puff transit.)}$$

Equation 10 provides the *effective* relative concentration for the puff. This value can be input to dose assessment codes such as RADTRAD or HABIT as any value of χ/Q would be if the intake flows, release duration, and release rates are modeled consistent with the inputs to Equation 10.

6.   PLUME RISE

An applicant or licensee may propose adjustments to the release height for plume rise that are due to buoyancy or mechanical jet on a case-by-case basis. In order to credit these adjustments, the applicant or licensee must be able to demonstrate that the assumed buoyancy or vertical velocity of the effluent plumes will be maintained throughout the time intervals that plume rise is credited. Such justifications need to consider the availability of AC power, failure modes of dampers and ductwork, time-dependent release stream temperatures and pressures, and 95th-percentile wind speeds and ambient temperatures.[13] Plume rise may be considered for freestanding stacks and for vents located on plant buildings. However, plume rise may not be used in demonstrating that a particular stack meets the 2-1/2 times the adjacent structure height criterion in Regulatory Position 3.2.2. A mixed-mode release model, such as that in Regulatory Guide 1.111 (Ref. 10), should not be used for design basis assessments.

The plume rise may be determined through the use of the following set of equations (Ref. 17). The plume rise for plant vents is determined using Equation 11. The distance x is entered as the horizontal distance between the vent and the control room outside air intake.

The plume rise for isolated, free-standing stacks is calculated using Equations 11, 12, and 13. The distance x in Equation 11 should be based on the downwind location corresponding to the maximum χ/Q value. See Regulatory Position 3.2.2. The plume rises calculated using Equations 12 and 13 should be compared and the larger plume rise identified. The result of this comparison is then compared to the plume rise determined using Equation 11 and the smaller plume rise selected for use.

$$\Delta h = \left[\frac{3}{\beta_1^2} \cdot \frac{F_m}{U^2} \cdot x + \frac{3}{2\beta_1^2} \cdot \frac{F_b}{U^3} \cdot x^2 \right]^{1/3} \tag{11}$$

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[13] As used here, 95th-percentile wind speed is that wind speed that is not exceeded more than 5 percent of the time. A 95th-percentile ambient temperature is that temperature that is not exceeded more than 5 percent of the time.

$$\Delta h = 2.6 \cdot \left(\frac{F_b}{Us} \right)^{1/3} \tag{12}$$

$$\Delta h = 2.44 \cdot \left(\frac{F_m}{s} \right)^{1/4} \tag{13}$$

Where:

Δh	=	Plume rise, m
F_m	=	Momentum flux parameter, $m^4 \cdot s^{-2}$
	=	$\dfrac{\rho_o V_o w_o}{\pi \rho_a}$
β_1	=	Dimensionless entrainment constant for momentum = 0.6
U	=	Wind speed at release height, $m \cdot s^{-1}$
x	=	Distance from release point to receptor, m (see text)
F_b	=	Buoyancy flux parameter, $m^4 \cdot s^{-3}$
	=	$\dfrac{g(\rho_a - \rho_o)V_o}{\pi \rho_a}$
w_o	=	Effluent exit velocity, $m \cdot s^{-1}$
V_o	=	Volumetric release rate, $m^3 \cdot s^{-1}$
ρ_o	=	Effluent density after expansion to atmospheric pressure, $kg \cdot m^{-3}$
ρ_a	=	Density of air, $kg \cdot m^{-3}$
s	=	0.0001 s^{-2} for A, B, C, and D stability; 0.00049 s^{-2} for E stability; 0.0013 s^{-2} for F stability; 0.002 s^{-2} for G stability
g	=	Gravitational acceleration, 9.8 $m \cdot s^{-2}$

Although ARCON96 processes ambient meteorological conditions on an hour-by-hour basis, the code cannot vary the other parameters that enter into a plume rise determination. For example, wind speed and stability class are varied hour by hour, but the density of air, the density of the effluent stream, and the vertical velocity are not varied hour-by-hour. As such, the analyst should ensure that these parameters are bounding for the entire period of the χ/Q assessment or use individual time intervals to model the time-variant parameters. An alternative approach would be to calculate the plume rise for each hour independently of ARCON96 and to select a plume rise that is exceeded more than 95 percent of the time. This rise is then added to the stack height as input to ARCON96.

In lieu of mechanistically addressing the amount of buoyant plume rise associated with energetic releases from steam relief valves or atmospheric dump valves, the ground level χ/Q value calculated with ARCON96 (on the basis of the physical height of the release point) may be reduced[14] by a factor of 5. This reduction may be taken only if (1) the release point is uncapped and vertically oriented and (2) the time-dependent vertical velocity exceeds the 95th-percentile wind speed[13] (at the release point height) by a factor of 5.

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[14] This adjustment factor and the associated velocity ratio criterion are deterministic in nature and their selection was based on sensitivity analyses performed for typical steam release points at LWRs. The adjustment factor should not be ratioed for different vertical velocity ratios.

7.   USE OF SITE-SPECIFIC EXPERIMENTAL DATA

The methods and parameters provided in this guide are acceptable for use for design basis control room habitability radiological assessments provided that all stated prerequisites and conditions are met. The staff believes that use of the guidance in this guide will result in χ/Q values that are acceptably conservative. However, there may be circumstances in which these methods and parameters may not be advantageous for a particular plant configuration and site meteorological regimes and may lead to results that are deemed to be unnecessarily conservative. Licensees and applicants may opt to propose alternative methods and parameters such as those that are based in part on data obtained from site-specific experimental measurements. Data based on wind tunnel tests should be accompanied with an evaluation of the representativeness of the experiment results to the particular plant configuration and site meteorological regimes. These proposed alternatives, with supporting data, will be considered by the staff on a case-by-case basis.

The staff recommends that licensees considering an experimental program request a meeting with the staff in advance of starting the program. The intent of this recommendation is to allow the staff and the licensee (or applicant) to discuss the proposed program, prior to resource expenditure, and for the staff to provide a preliminary assessment of the proposal. The staff's approval of the proposed alternative methods and parameters will not be granted, however, until the licensee or applicant completes the experimental program and dockets the proposal with supporting analyses and data for formal staff review.

An acceptable experimental program should incorporate the following standards:

7.1   The experimental program should be appropriately structured so as to provide data of appropriate quantity and quality to support data analysis and conclusions drawn from that data. The program should be developed by personnel who have educational and work experience credentials in air dispersion meteorology and modeling.

7.2   The experimental program should encompass a sufficient range of meteorological conditions applicable to the particular site so as to ensure that the data obtained address the site-specific meteorological regimes and the site-specific release point/receptor configurations that impact the control room χ/Q values. Meteorological conditions observed at the particular site with a frequency of 5 percent or greater in a year should be addressed. Parameters derived from statistical analyses on the experimental data should represent the 95th-percentile confidence level.

7.3   The experimental program, including data reduction and analysis, should incorporate applicable quality control criteria of Appendix B to 10 CFR Part 50. The products of the experimental program should be verified and validated.

D. IMPLEMENTATION

The purpose of this section is to provide information to licensees and applicants regarding the NRC staff's plans for using this regulatory guide. No backfitting is intended or approved in connection with the issuance of this guide.

Except when an applicant or licensee proposes an acceptable alternative method for complying with the specified portions of the NRC's regulations pertaining to control room habitability, the methods described in this guide will be used in the evaluation of the compliance with these regulations in (1) license amendments at operating reactors, (2) combined operating license applications, (3) construction permit applications, (4) operating license applications, and (5) design certification applications.
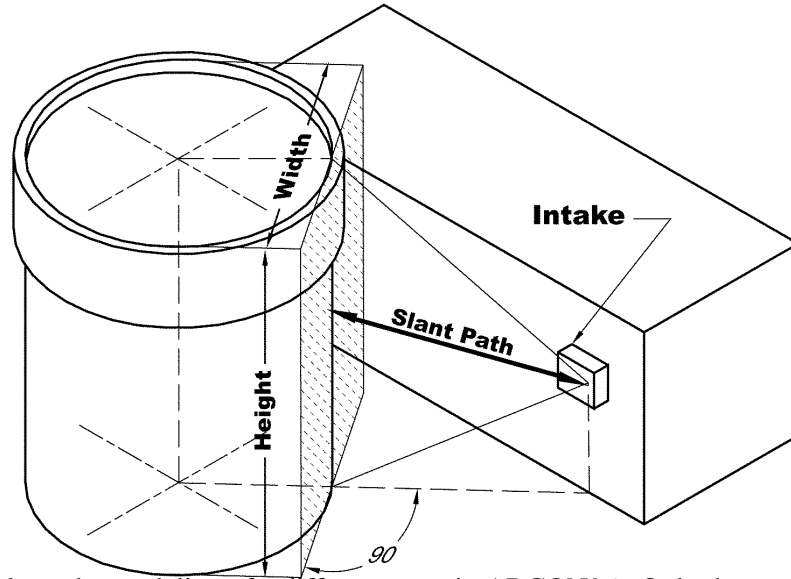
Figure 1

ZONE OF INFLUENCE FOR STACKS
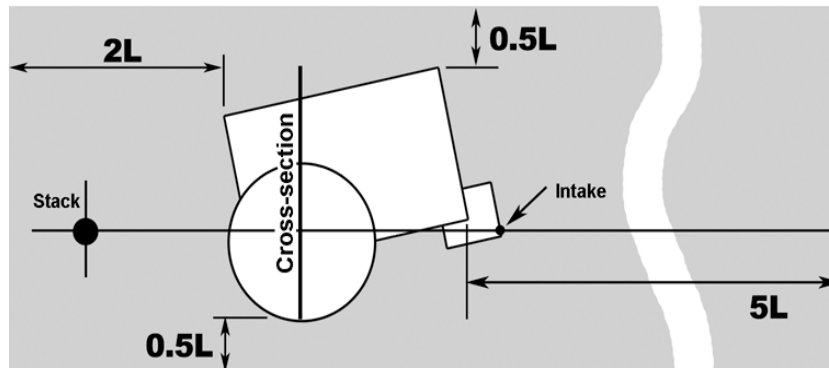
Note: In this example, L is taken has the height or width, whichever is less, of the building cluster cross-section perpendicular to the wind. A stack located inside the zone should be 2.5 times (2.5X) the height of the structure that causes the building wake. The zone will change with wind direction and, depending on the building arrangement, there may be overlapping zones. For example, a stack located at 5L could not be considered "freestanding" if that point was within 2L of a downwind building. For control room applications, wind directions in the 90 degree sector centered on the line of sight between the stack and the intake should be considered when defining the cross-section and L.

Figure 2

ARCON96 DIFFUSE SOURCE MODELING

This figure applies only to the modeling of a diffuse source in ARCON96. Only that part of the structure above grade or an enclosing building should be included in the building height. However, the height need not be reduced for an adjacent building if the assumed building surface release can be reasonably transported around or over the building to the intake.
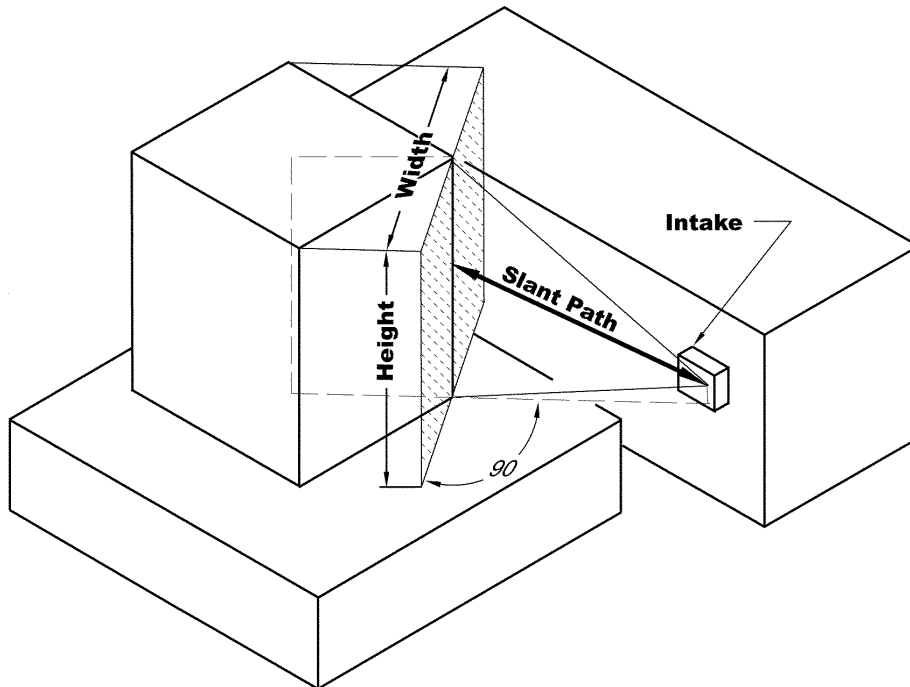
Figure 3
ALTERNATIVE LOCATIONS FOR DUAL INTAKES

(a)

Wind direction window
(assuming release point
on top of containment)

(b)

(c)

(d)
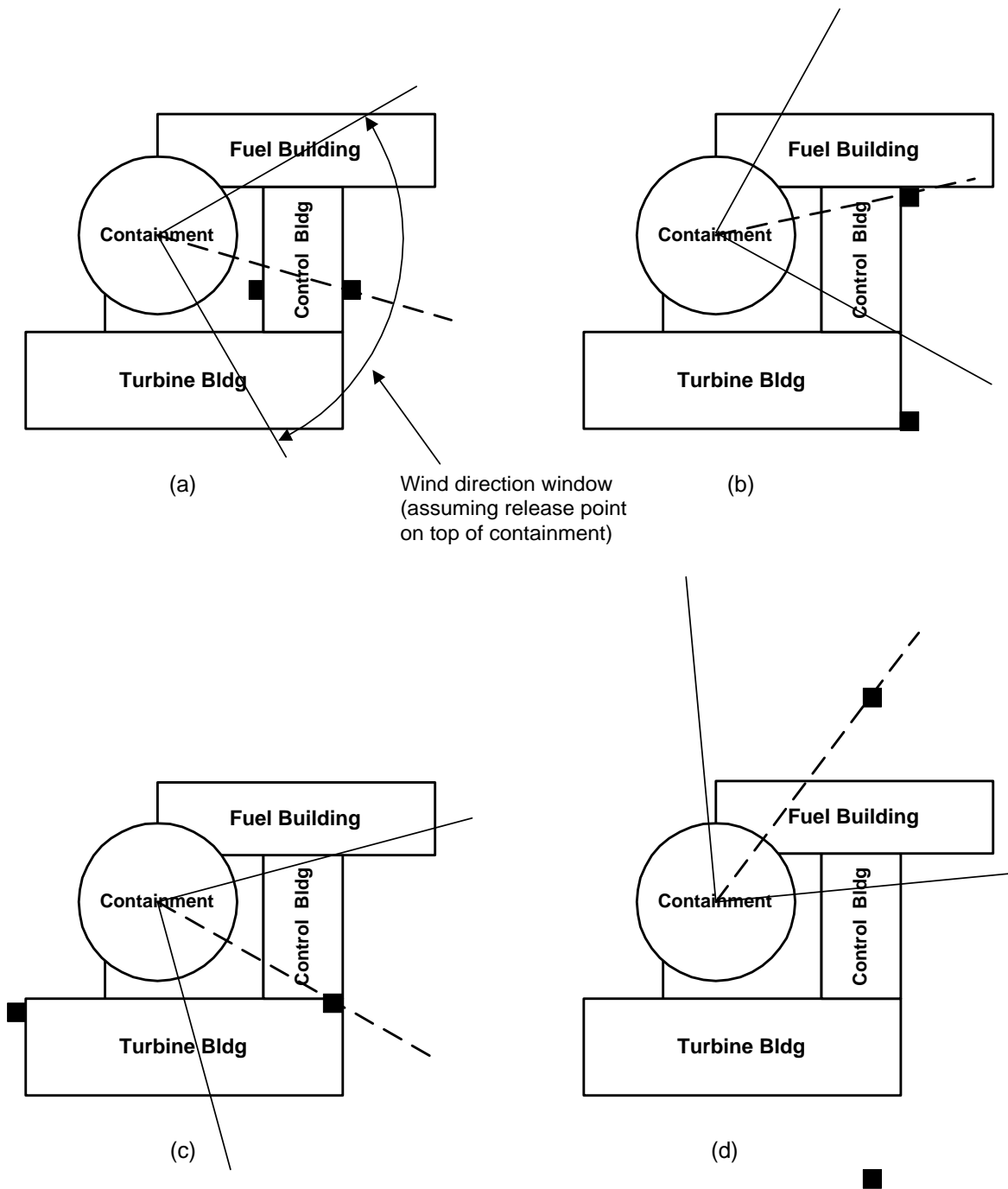
These figures apply when using the methodology described in Regulatory Position 3.3.2.

Figure 4
LATERAL DISPERSION COEFFICIENT vs DISTANCE AND STABILITY CLASS
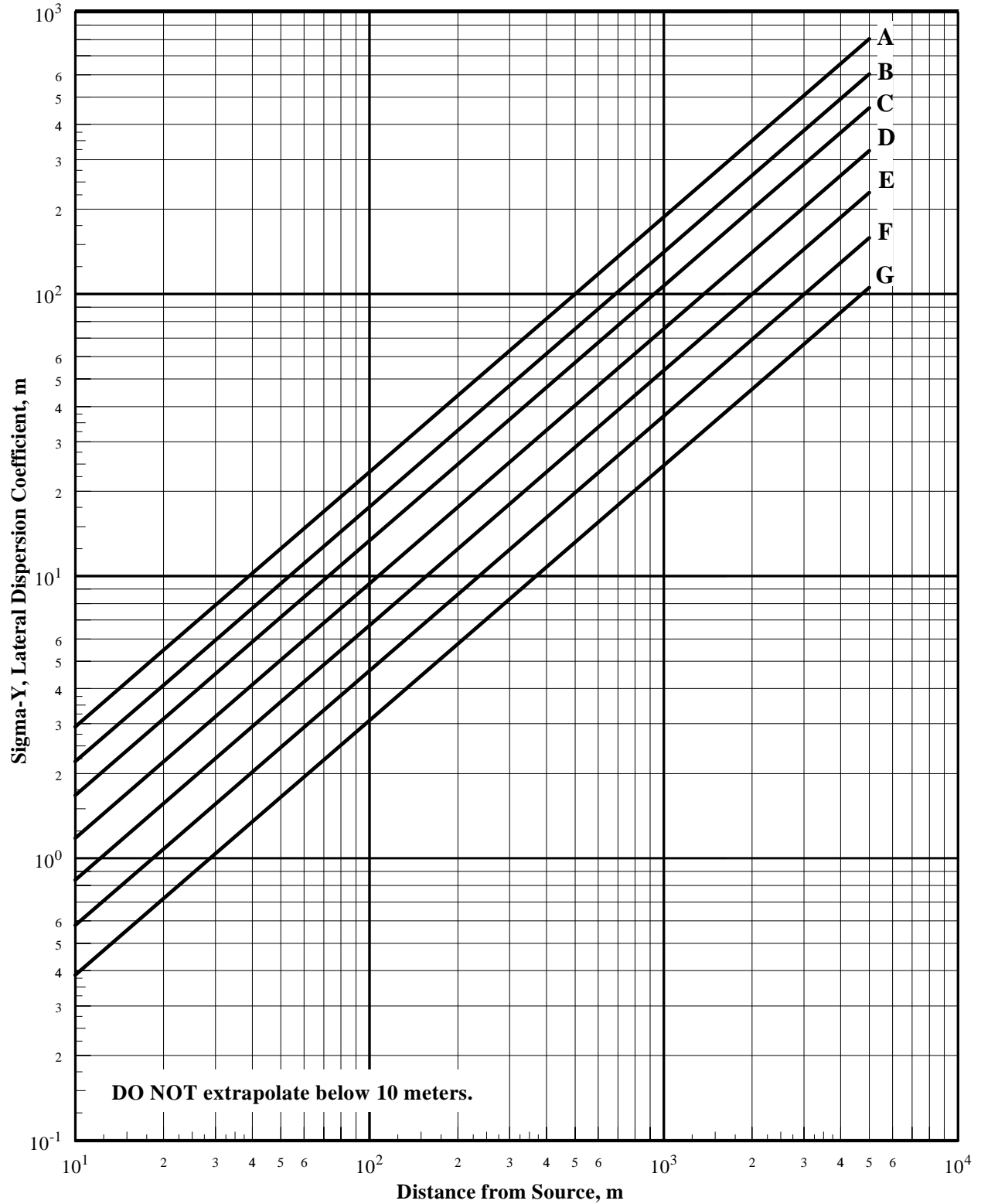
Calculated using method of POLYN subroutine in PAVAN (Ref. 14);
also Eimultis and Konicek (Ref. 18)

Figure 5
VERTICAL DISPERSION COEFFICIENT vs DISTANCE AND STABILITY CLASS
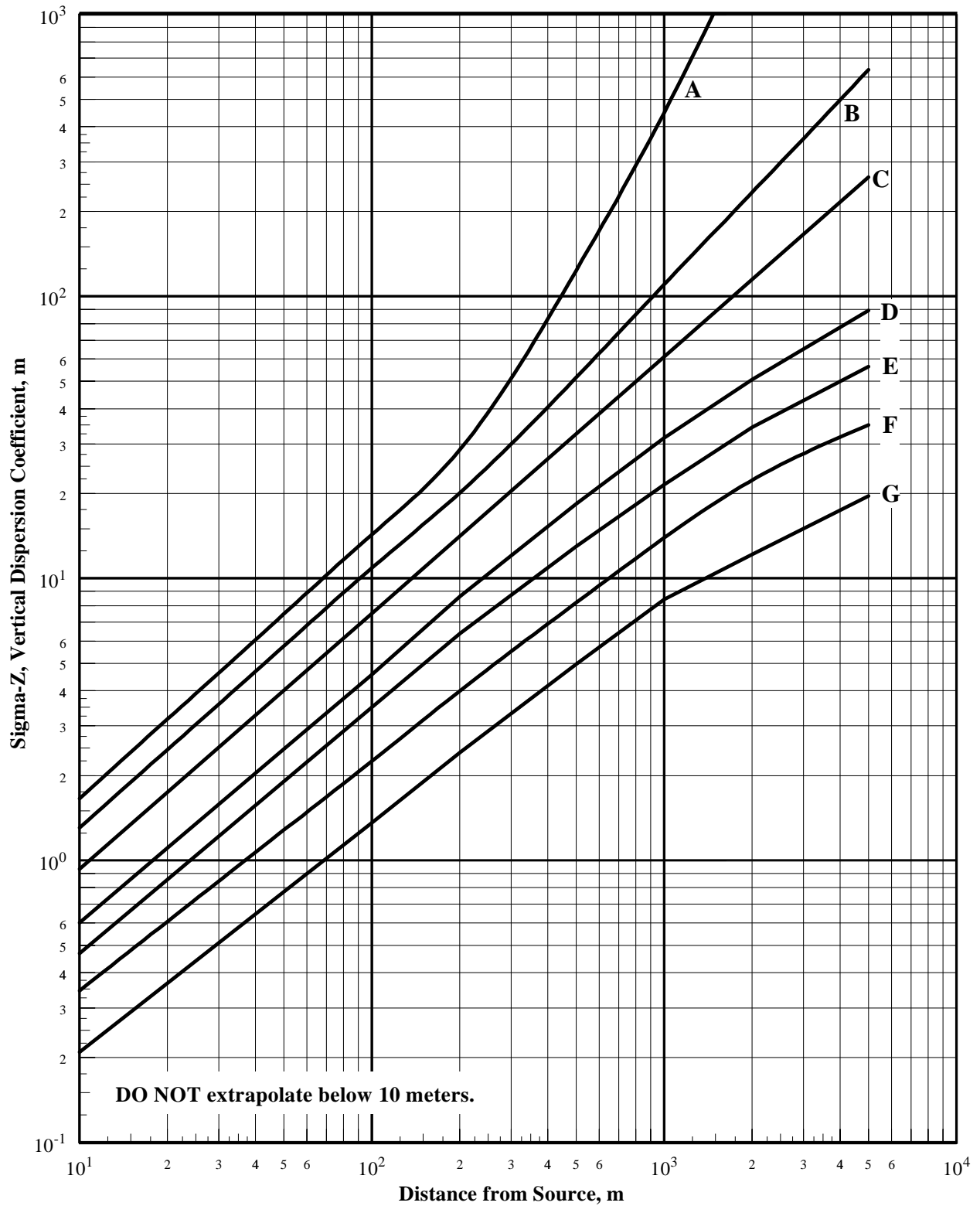
Calculated using method of POLYN subroutine in PAVAN (Ref. 14);
also Eimultis and Konicek (Ref. 18)

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9.   USNRC, "Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants," Regulatory Guide 1.145, Revision 1, November 1982.[2]

10.   USNRC, "Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors," Regulatory Guide 1.111, Revision 1, July 1977.[2]

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[1] Copies are available at current rates from the U.S. Government Printing Office, P.O. Box 37082, Washington, DC 20402-9328 (telephone (202)512-1800); or from the National Technical Information Service by writing NTIS at 5285 Port Royal Road, Springfield, VA 22161; < telephone (703)487-4650. Copies are available for inspection or copying for a fee from the NRC Public Document Room at 11555 Rockville Pike, Rockville, MD; the PDR's mailing address is USNRC PDR, Washington, DC 20555; telephone (301)415-4737 or (800)397-4209; fax (301)415-3548; email is PDR@NRC.GOV.

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18.   E.C. Eimutis and M.G. Konicek, "Derivations of Continuous Functions for the Lateral and Vertical Atmospheric Dispersion Coefficients," *Atmospheric Environment*, Vol 6, pp. 859-863, Pergamon Press, 1972.

Appendix A
ARCON96 METEOROLOGICAL DATA SET STRUCTURE

The meteorological data set is input to the ARCON96 code as one or more data files composed of a series of records, each of which contains the data for one hourly observation. Data should be reviewed to ensure that parameter conversions or normalizations have been made properly. These data should be input to ARCON96 in chronological order. ARCON96 can accept up to 10 separate meteorological data files in a single run. Each individual file may contain the data for one year, a fraction of a year, or multiple years. ARCON96 will process the data in blocks of 10,000 records, spanning files as necessary, until all data are processed. The file is a formatted, ASCII text data file. The format of each record is shown in Table A-1. Table A-2 discusses input parameters for ARCON96.

Table A-1
ARCON96 METEOROLOGICAL DATA SET[1]

Field	Parameter	Discussion
1X	One blank space	
A4	Identifier	Any four character string to identify file. Can be used for any purpose, site name, etc.
I4	Calendar year	Four digit calendar year.
I3	Julian date of observation	1-365 or 1-366 (leap year) as an integer.
I2	Hour of day of observation	Local time, 24-hour clock, 0-23, with midnight = 0 as an integer.
2X	Two blank spaces	
I3	Lower-level wind direction	In degrees from which wind is blowing as an integer. A wind from the north is entered as 360 and a wind from the south is entered as 180.
I4	Lower-level wind speed	In mph, $m \cdot s^{-1}$, or knots, entered to the nearest tenth of the reporting unit[2] with the decimal point assumed. For example, 5.3 $m \cdot s^{-1}$ is entered as 53, 5 meters/second as 50, etc.
1X	One blank space	
I2	Stability class	As an integer, A=1, G=7. If determined using ΔT, the vertical temperature difference is that measured over the difference in elevation appropriate for the projected release height.[3]
2X	Two blank spaces	
I3	Upper-level wind direction	In degrees from which wind is blowing as an integer. A wind from the north is entered as 360 and a wind from the south is entered as 180.
I4	Upper-level wind speed	In mph, $m \cdot s^{-1}$, or knots, entered to the nearest tenth of the reporting unit[2] with the decimal point assumed. For example, 5.3 $m \cdot s^{-1}$ is entered as 53, 5 meters/second as 50, etc.

Notes:
(1) Invalid data should be represented by the field completely filled with 9s. For example, "999" for a I3 field, "999" for a I4 field.

(2) The analyst selects the reporting unit on an ARCON96 dialog form during the code run. ARCON96 analysts need to ensure that the measurement unit used to represent wind speed in the data set corresponds to the measurement unit selected on the dialog form.

(3) The stability classification table in Safety Guide 23 assumes that ΔT is expressed in units of °C/100m. Analysts need to ensure that the site-specific values are converted to the same units used in Safety Guide 23.

For example, for 0500 on the 165th day of 2002, with a level 1 wind direction of 78°, a level 1 wind speed of 5.3 mph, a stability class of A ("1"), and a level 2 wind direction of 180°, and a level 2 wind speed of 10.1 mph, the record would read (□ = blank).

□TEST200216505□□0780053□1□□1800101

Table A-2
ARCON96 INPUT PARAMETERS FOR DESIGN BASIS ASSESSMENTS

Parameter	Discussion	Acceptable Input
Lower Measurement Height, meters	The value of this parameter is used by ARCON96 to adjust wind speeds for differences between the heights of the instrumentation and the release.	Use the actual instrumentation height when known. Otherwise, assume 10 meters.
Upper Measurement Height, meters	The value of this parameter is used by ARCON96 to adjust wind speeds for differences between the heights of the instrumentation and the release.	Use the actual instrumentation height when known. Otherwise, use the height of the containment or the stack height, as appropriate. If wind speed measurements are available at more than two elevations, the instrumentation at the height closest to the release height should be used.
Wind Speed Units	ARCON96 requires that wind speed be entered as miles per hour, m·s^{-1}, or knots.	Use the wind speed units that correspond to the units of the wind speeds in the meteorological data file.
Release Height, meters	The value of the release height is used for three purposes in ARCON96: (1) to adjust wind speeds for differences between the heights of the instrumentation and the release, (2) to determine slant path for ground level releases, (3) to correct off-centerline data for elevated releases.	Use the actual release heights whenever available. Plume rise from buoyancy and mechanical jet effects may be considered in establishing the release height if the analyst can demonstrate with reasonable assurance that the vertical velocity of the release will be maintained during the course of the accident. If actual release height is not available, set release height equal to intake height.
Building Area, meters^2	ARCON96 uses the value of the building area in the high speed wind speed adjustment for ground-level and vent release models.	Use the actual building vertical cross-sectional area perpendicular to the wind direction. Use default of 2000 m^2 if the area is not readily available. Do not enter zero. Use 0.01 m^2 if a zero entry is desired. *Note: This building area is for the building(s) that has the largest impact on the building wake within the wind direction window. This is usually, but need not always be, the reactor containment. With regard to the diffuse area source option, the building area entered here may be different from that used to establish the diffuse source.*
Vertical Velocity, meters/second	In ARCON96, the value of the vertical velocity is used only in vent and stack release models. It is used for the downwash calculation. In the vent release model the velocity is used in the mixed-mode calculation. If the vertical velocity is set to zero, the maximum downwash will be calculated and the release height will be reduced by an amount equal to six times the stack radius.	*Note: the vent release model should not be used for DBA accident calculations.* For stack release calculations only, use the actual vertical velocity if the licensee can demonstrate with reasonable assurance that the value will be maintained during the course of the accident (e.g., addressed by technical specifications), otherwise, enter zero. If the vertical velocity is set to zero, ARCON96 will reduce the stack height by 6 times the stack radius for all wind speeds. If this reduction is not desired, the stack radius should also be set to zero.

Parameter	Discussion	Acceptable Input
Stack Flow, meters^3/second	ARCON96 uses the value of the stack flow in χ/Q calculations for all 3 release types to ensure that the near field concentrations are no greater than the concentration at the release point. The impact diminishes with increasing distance.	Use actual flow if it can be demonstrated with reasonable assurance that the value will be maintained during the course of the accident (e.g., addressed by technical specifications). Otherwise, enter zero. The flow is used in both elevated and ground-level release modes to establish a maximum χ/Q value. This value is significant only if the flow is large and the distance from the release point to the receptor is small.
Stack Radius, meters	ARCON96 uses the value of the stack radius in downwash calculations in the vent and stack release modes.	Use the actual stack internal radius when both the stack radius and vertical velocity are available. If the stack flow is zero, the radius should be set to zero.
Distance to Receptor, meters	The value of horizontal distance to the receptor from the release point is used in ARCON96 for calculating the slant range for ground level releases and the off-centerline correction factors for stack release models.	Use the actual straight line horizontal distance between the release point and the control room intake. For ground-level releases, it may be appropriate to consider flow around an intervening building if the building is sufficiently tall that it is unrealistic to expect flow from the release point to go over the building. *Note: If the distance to receptor is less than about 10 meters, ARCON96 should not be used to assess relative concentrations.*
Intake Height, meters	The value of the intake height is used in ARCON96 for calculating the slant range for ground level releases and the off-centerline correction factors for stack release models.	Use the actual intake height. If the intake height is not available for ground level releases, assume the intake height is equal to the release height. For elevated releases, assume the height of the tallest site building.
Elevation Difference, meters	The value of this parameter is used by ARCON96 to normalize the release heights and the intake heights when the two heights are specified as "above grade" with different grades for the release point and intake height, or when one measurement is referenced to "above grade" and the other to "above sea level."	Use zero unless it is known that the release heights are reported relative to different grades or reference data.
Direction to Source, degrees	ARCON96 uses the value of this parameter and the Wind Direction Window to establish which range of wind directions should be included in the assessment of the χ/Q.	Use the direction FROM the intake back TO the release point. (Wind directions are reported as the direction from which the wind is blowing. Thus, if the direction from the intake to the release point is north, a north wind will carry the plume from the release point to the intake.) *Note: some facilities have a "plant north" shown on site arrangement drawings that is different from "true north." The direction entered must have the same point of reference as the wind directions reported in the meteorological data.* For ground-level releases, if the plume is assumed to flow around a building rather than over it, the direction may need to be modified to account for the redirected flow. In this case, the χ/Q should be calculated assuming flow around and flow over (through) the building and the higher of the two χ/Q s should be used.

Parameter	Discussion	Acceptable Input
Surface Roughness Length, meters	ARCON96 uses the value of this parameter in adjusting wind speeds to account for differences in meteorological instrumentation height and release height.	Use a value of 0.2 in lieu of the default value of 0.1 for most sites. (Reasonable values range from 0.1 for sites with low surface vegetation to 0.5 for forest-covered sites.)
Wind Direction Window, degrees Code Default	ARCON96 uses the value of this parameter and the Direction to Source to establish which range of wind directions should be included in the assessment of the χ/Q.	Use the default window of 90 degrees (45 degrees on either side of line of sight from the source to the receptor).
Minimum Wind Speed, meters/second Code Default	ARCON96 uses the value of this parameter to identify calm conditions.	Use the default wind speed of 0.5 m·s^{-1} (regardless of the wind speed units entered earlier), unless there is some indication that the anemometer threshold is greater than 0.6 m·s^{-1}.
Averaging Sector Width Constant Code Default	ARCON96 uses the value of this parameter to prevent inconsistency between the centerline and sector average χ/Q s for wide plumes. Has largest effect on ground level plumes.	Although the default value is 4, a value of 4.3 is preferred. (A future revision to ARCON96 will change the default to 4.3)
Initial Diffusion Coefficients, meters	ARCON96 uses these parameters in modeling a diffuse source.	These values will normally be set to zero. If the diffuse source option is being used, see Regulatory Position 2.2.4.
Hours in Averages Code Default	The values of this parameter were selected to provide results for desired periods and to provide a smooth χ/Q curve.	Use the default values.
Minimum Number of Hours Code Default	The default values of this parameter will allow processing with up to 10% missing data.	Use the default values.

REGULATORY ANALYSIS

A separate regulatory analysis was not prepared for this regulatory guide. The regulatory analysis prepared for the draft of this guide, Draft Regulatory Guide DG-1111, "Atmospheric Relative Concentrations for Control Room Radiological Habitability Assessments at Light-Water Nuclear Power Reactors" (December 2001), provides the regulatory basis for this regulatory guide as well. DG-1111 was issued for public comment as the draft of this present regulatory guide. A copy of DG-1111 with the regulatory analysis is available for inspection and copying for a fee at the U.S. Nuclear Regulatory Commission Public Document Room, 11555 Rockville Pike, Rockville, MD; the PDR's mailing address is USNRC PDR, Washington, DC 20555; telephone (301) 415-4737 or 1-(800) 397-4209; fax (301) 415-3548; e-mail <PDR@NRC.GOV>. An electronic copy of DG-1111 with the regulatory analysis is also available in the NRC's Electronic Reading Room under ADAMS with Accession Number ML013130132.