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METHODS FOR ESTIMATING ATMOSPHERIC TRANSPORT AND DISPERSION OF GASEOUS EFFLUENTS IN ROUTINE RELEASES FROM LIGHT-WATER-COOLED REACTORS

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A. INTRODUCTION

Section 20.106, "Radioactivity in Effluents to Unrestricted Areas," of 10 CFR Part 20, "Standards for Protection Against Radiation," establishes limits on concentrations of radioactive material in effluents to unrestricted areas. Paragraph 20.1(c) of 10 CFR Part 20 states that licensees should, in addition to complying with the limits set forth in that part, make every reasonable effort to maintain radiation exposures, and releases of radioactive materials in effluents to unrestricted areas, as far below the limits specified in that part as is reasonably achievable.

Section 50.34a, "Design Objectives for Equipment to Control Releases of Radioactive Material in Effluents - Nuclear Power Reactors," of 10 CFR Part 50, "Licensing of Production and Utilization Facilities," sets forth design objectives for equipment to control releases of radioactive material in effluents from nuclear power reactors. Section 50.36a, "Technical Specifications on Effluents from Nuclear Power Reactors," of 10 CFR Part 50 further provides that, in order to keep power reactor effluent releases as low as is reasonably achievable, each license authorizing operation of such a facility will include technical specifications that require establishment of operating procedures for effluent control, installation and maintenance of effluent control equipment, and reporting of actual releases.

Appendix I, "Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion 'As Low As Is Reasonably Achievable' for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents," to 10 CFR Part 50 provides numerical guidance for those design objectives and limiting conditions for operation for light-water-cooled nuclear power plants. To implement Appendix I, the NRC staff has developed a series of guides providing acceptable methods for the calculation of effluent releases, dispersion of the effluent in the atmosphere and water bodies, and associated radiation doses to man. This guide describes basic features of calculational models and assumptions for the estimation of atmospheric transport and dispersion of gaseous effluents in routine releases from land-based light-water-cooled reactors.

The procedures and models provided in this guide will be subject to continuing review by the staff with the aim of providing greater flexibility to the applicant in meeting the requirements of Appendix I. As a result of such review, it is expected that alternative acceptable methods for calculation will be made available to applicants and that calculational procedures found to be unnecessary will be eliminated.

This guide supersedes portions of Regulatory Guide 1.42, Revision 1, "Interim Licensing Policy on As Low As Practicable for Gaseous Radioiodine Releases from Light-Water-Cooled Nuclear Power Reactors," which has been withdrawn (see 41 FR 11891, 3/22/76). | *

B. DISCUSSION

The transport and dilution of radioactive materials in the form of aerosols, vapors, or gases released into the atmosphere from a nuclear power station are a function of the state of the atmosphere along the plume path, the topography of the region, and the characteristics of the effluents themselves. For a routine airborne release, the concentration of radioactive material in the surrounding region depends on the amount of effluent released; the height of the release; the momentum and buoyancy of the emitted plume; the windspeed, atmospheric stability, and airflow patterns of the site; and various effluent removal mechanisms. Geographic features such as hills, valleys, and large bodies of water greatly influence dispersion and airflow patterns. Surface roughness, including vegetative cover, affects the degree of turbulent mixing. Sites with similar topographical and climatological features can have similar dispersion and airflow patterns, but detailed dispersion patterns are usually unique for each site.

Most gaseous effluents are released from nuclear power plants through tall stacks or vents near the tops of buildings. Certain plant designs can result in other release pathways. For example, auxiliary equipment and major components such as turbines may be housed outside buildings; releases from these components could occur near ground level.

1. Diffusion Models

Atmospheric diffusion modeling has developed along two basic approaches: gradient-transport theory and statistical theory. Gradient-transport theory holds that diffusion at a fixed point

*Lines indicate substantive changes from previous issue.

in the atmosphere is proportional to the local concentration gradient; this theory attempts to determine momentum or material fluxes at fixed points. The statistical (e.g., Gaussian) approach attempts to determine the histories of individual particles and the statistical properties necessary to represent diffusion. Input data for models based on either approach include windspeed, atmospheric stability, and airflow patterns in the region of interest. Several basic models have been developed using these approaches. These models vary according to their treatment of the spatial changes of input data and the consideration of either a variable trajectory model or a constant mean wind direction model.

a. Variable Trajectory Models

Variable trajectory models allow conditions to vary spatially and temporally over the region of interest; thus, they require regional data. The number of sampling locations needed to approximate the regional airflow depends on the meteorological and topographical characteristics of that region.

The particle-in-cell model is a variable trajectory model based on the gradient-transport approach. In this model, "particles" representing the effluent mass are released in groups over the time period of interest. The particles move at the effective transport velocity of the windflow field into which the effluent is released. The effective velocity is determined by the mean and turbulent windflows within the field. The number of particles located at any given time in each cell (volume) of a fixed coordinate grid determines the effluent concentration. Concentration averages are determined from the total number of particles that pass through a cell during the time of interest.

The plume element models, another class of variable trajectory models, are based on the statistical approach to diffusion. These models approximate a continuous release by dividing a plume into a sufficient number of plume elements to represent a continuous plume. These elements are released at specified intervals and are tracked over the region of interest. The advective transport of these elements and the diffusion of the elements about their individual centers cause the dispersion of the plume effluent. Concentration averages are calculated by determining the contribution each element makes to the grid of points over which it passes.

b. Constant Mean Wind Direction Models

Constant mean wind direction models assume that a constant mean wind transports and diffuses effluents, within the entire region of interest, in the direction of airflow at the release point. A commonly used version of this model is the Gaussian straight-line trajectory model. In this model, the windspeed and atmospheric stability at the release point are assumed to determine the atmospheric dispersion characteristics in the direction of the mean wind at all distances.

These basic models can be modified to account for various modes of effluent release and for effluent removal mechanisms.

2. Release Mode

At ground-level locations beyond several miles from the plant, the annual average concentrations of effluents are essentially independent of the release mode; however, for ground-level concentrations within a few miles, the release mode is very important.

For a typical nuclear power plant, gaseous effluents released from tall stacks generally produce peak ground-level air concentrations near or beyond the site boundary; near-ground-level releases usually produce concentrations that monotonically decrease from the release point to all locations downwind. Under certain conditions, the effluent plume may become entrained in the aerodynamic wake of the building and mix rapidly down to ground level; under other conditions, the full effect of the elevation of the release may be realized.

Methods have been developed to estimate the effective release height for calculations of effluent concentrations at all downwind locations. The important parameters in these methods include the initial release height, the location of the release point in relation to obstructions, the size and shape of the release point, the initial vertical velocity of the effluent, the heat content of the effluent, ambient windspeed and temperature, and atmospheric stability.

For those effluents that are entrained into the aerodynamic wake of a building, mixing of the effluent into the wake is usually assumed. This mixing zone can constitute a plume with an initial cross section of one-half or more of the cross-sectional area of the building.

3. Removal Mechanisms

As the effluent travels from its release point, several mechanisms can work to reduce its concentration beyond that achieved by diffusion alone. Such removal mechanisms include radioactive decay and dry and wet deposition.

Radioactive decay is dependent on the half-life and the travel time of the radioactive effluent. All effluents can undergo dry deposition by sorption onto the ground surface; however, the dry deposition rate for noble gases, tritium, carbon-14, and nonelemental radioiodines is so slow that depletion is negligible within 50 miles of the release point. Elemental radioiodines and other particulates are much more readily deposited. The transfer of elemental radioiodines and particulates to a surface can be quantified as a transfer velocity (where concentration x transfer velocity = deposition rate). There is evidence that the transfer velocity is directly proportional to windspeed and, as a consequence, the rate of deposition is independent of windspeed since concentration in air is inversely proportional to windspeed.

Dry deposition is a continuous process while wet deposition only occurs during periods of precipitation. However, the dry removal process is not as efficient as the wet removal process. At most sites, precipitation occurs during a small percentage of the hours in a year so that, despite the greater efficiency of the wet removal process, dose calculations for long-term averages considering only dry deposition should not be significantly changed by the consideration of wet deposition. However, wet deposition can be a significant factor in dose calculations for releases from stacks at sites where a well-defined rainy season corresponds to the local grazing season.

Deposition of radionuclides over large bodies of water is not considered in this guide. Such deposition will be analyzed on a case-by-case basis.

C. REGULATORY POSITION

This section identifies types of atmospheric transport and diffusion models, source configuration and removal mechanism modifications, and input data that are acceptable to the NRC staff for use in providing assessments of potential annual radiation doses to the public resulting from routine releases of radioactive materials in gaseous effluents.

The listing of the atmospheric transport and diffusion models below is presented in order of decreasing model complexity and should not be construed as indicating the preference of any one type of model over another. The preferred model is that which best simulates atmospheric transport and diffusion in the region of interest from source to the receptor location, considering the meteorological characteristics of the region, the topography, the characteristics of the effluent source and the effluent as well as the receptor, the availability and representativeness of input data, the distance from source to receptor, and the ease of application.

Models proposed by the applicant and accepted by the NRC staff will be used by the staff in determining environmental technical specifications.

1. Atmospheric Transport and Diffusion Models

The following types of atmospheric transport and diffusion models can be modified for elevated sources and for effective area sources created when effluent is trapped in the building wake cavity in accordance with the source configuration considerations presented in regulatory position 2. Plume rise due to momentum or buoyancy effects can also be incorporated into the calculations. Radiological decay and dry and wet deposition, consistent with the guidelines presented in regulatory position 3, should also be considered.

a. Particle-in-Cell (PIC) Model

The basic equation for each "particle" group in this variable trajectory model, modified from Sklarew (Ref. 1), is:

$$\delta(\overline{\chi})/\delta t + \nabla \cdot V(\overline{\chi}) = 0 \qquad (1)$$

where

t is the travel time;

V is the velocity vector for effective mean wind transport, which includes the mean flow component, $\overline{V}$, and the turbulent flow component, V', such that $V = \overline{V}+V'$; and

$(\overline{\chi})$ is the average atmospheric concentration produced by a group of particles.

Concentration averages for long time intervals are obtained by summing all "particles" passing through each grid cell during the period of interest.

The PIC model uses spatial and temporal variations of wind direction, windspeed, atmospheric stability, and topography as input parameters to define airflow and atmospheric diffusion rates. The representativeness of the input data determines the accuracy of estimates (i.e., fewer data acquisition locations tend to increase the uncertainty of the estimates); therefore, detailed discussion of the applicability and accuracy of the model and input data used should be provided.

b. Plume Element Models

In these types of models, the transport and dispersion of an effluent plume are determined by using a horizontal wind field that can vary in time and space. The diffusion of individual plume elements, according to Gifford (Ref. 2), can be determined from the general Gaussian diffusion model. Commonly used plume segment elements are vertical "disk" segments and three-dimensional "puffs." In using the "puff" version, if it is assumed that the plume spread within a puff along the direction of flow is equal to the spread in the lateral direction, the "disk segment" and "puff" versions of this model would be expected to yield similar results.

An equation for a "puff" version of a fluctuating plume model, as presented by Start and Wendel (Ref. 3), is:

$$\chi/Q = 2[(2\pi)^{3/2}\sigma_H^2\sigma_z]^{-1}\exp[-1/2(r^2/\sigma_H^2 + h_e^2/\sigma_z^2)] \qquad (2)$$

where

$$r^2 = (x - \overline{u}t)^2 + y^2 \text{ and}$$

$$\sigma_H = \sigma_y = \sigma_x$$

and where

h_e is the effective release height;

Q is the effluent emission over the time interval;

t is the travel time;

$\overline{u}$ is the mean windspeed at the height of the effective release point;

x is the distance from center of puff along the direction of flow;

y is the distance from center of puff in the crossflow direction;

σ_x is the plume spread along the direction of flow;

σ_y is the lateral plume spread;

σ_z is the vertical plume spread; and

χ is the atmospheric concentration of effluent in a puff at ground level and at distance x from the puff center.

Concentration averages for long time intervals should be calculated by summing the concentrations of individual elements for the grid of points over which they pass.

The number of elements and the plume spread parameters (σ_x, σ_y, and σ_z) should be selected such that the resulting concentration estimate is representative of the concentration from a continuous point source release. Elements should be followed in the computational scheme until they are beyond the region of interest or until their peak concentration falls below a specified value.

The plume segment model uses spatial and temporal variations of wind direction, windspeed, and atmospheric stability as input parameters to define the transport and diffusion rate of each element. The effectiveness of the meteorological input data in defining atmospheric transport and diffusion conditions is dependent on the representativeness of these data and the complexity of the topography in the site region; therefore, a detailed discussion of the applicability and accuracy of the model and input data used should be provided.

c. <u>Constant Mean Wind Direction Models</u>

The equation for this model, as presented by Sagendorf (Ref. 4), is:

$$(\overline{\chi/Q'})_D = 2.032 \sum_{ij} n_{ij}[NX\bar{u}_i \Sigma_{zj}(X)]^{-1} \exp[-h_e^2/2\sigma_{zj}^2(X)] \quad (3)$$

where

h_e is the effective release height (see regulatory position 2);

n_{ij} is the length of time (hours of valid data) weather conditions are observed to be at a given wind direction, windspeed class, i, and atmospheric stability class, j;

N is the total hours of valid data;

$\bar{u}_i$ is the midpoint of windspeed class, i, at a height representative of release;

X is the distance downwind of the source;

$\sigma_{zj}(X)$ is the vertical plume spread without volumetric correction at distance, X, for stability class, j (see Figure 1);

$\Sigma_{zj}(X)$ is the vertical plume spread with a volumetric correction (see regulatory position 2.c) for a release within the building wake cavity, at a distance, X, for stability class, j; otherwise $\Sigma_{zj}(X) = \sigma_{zj}(X)$;

$(\overline{\chi/Q'})_D$ is the average effluent concentration, χ, normalized by source strength, Q', at distance, X, in a given downwind direction, D; and

2.032 is $(2/\pi)^{1/2}$ divided by the width in radians of a 22.5° sector.

Effects of spatial and temporal variations in airflow in the region of the site are not described by the constant mean wind direction model. Unlike the variable trajectory models, the constant mean wind direction model can only use meteorological data from a single station to represent diffusion conditions within the region of interest. For Appendix I considerations, the region of interest can extend to a distance of 50 miles from the site. Therefore, if the constant mean wind direction model is to be used, airflow characteristics in the vicinity of any site should be examined to determine the spatial and temporal variations of atmospheric transport and diffusion conditions and the applicability of single station meteorological data to represent:

(1) Conditions between the site and the nearest receptors (generally within 5 miles) and

(2) Conditions out to a distance of 50 miles from the site.

Examples of spatial and temporal variations of airflow to consider for three basic categories of topography are:

(1) At inland sites in open terrain, including gently rolling hills, with airflow dominated almost entirely by large-scale weather patterns, recirculation of airflow and directional biases during periods of prolonged atmospheric stagnation;

(2) At sites in pronounced river valleys, with airflow patterns largely dominated by terrain, restrictions to lateral and vertical spread of the effluent plume, and the diurnal distributions of downvalley and upvalley circulation, with particular attention to the period of flow reversal; and

(3) At sites along and near coasts of large bodies of water, with significant land-water boundary layer effects on airflow, sea (or lake) land breeze circulation (including

distance of penetration, vertical development, temporal variations of wind direction, and conditions during periods of flow reversal), variation of the mixing layer height with time and distance from the shore (e.g., fumigation and plume trapping), and the effects of shoreline bluffs and dunes.

Therefore, adjustments to Equation (3) may be necessary to prevent misrepresentation of actual atmospheric transport and diffusion characteristics that could result in substantial underestimates of actual exposure to an individual or population. Adjustments to Equation (3) should be based on data (e.g., comparison to other sites in the region) or studies that characterize airflow patterns in the region of the site out to a distance of 50 miles.

For all sites, a detailed discussion of the applicability and accuracy of the model and input data should be provided. Use of Equation (3) will be acceptable only if a well-documented and substantiated discussion of the effects of spatial and temporal variations in airflow in the region of the site out to a distance of 50 miles is provided.

2. Source Configuration Considerations

The actual height above ground of the gaseous effluent plume should be considered in making estimates of average effluent concentrations downwind from the release points. An acceptable method to determine the effective plume height is described below. In addition, for effluent plumes traversing irregular terrain under stable or neutral atmospheric conditions, the model described by Egan (Ref. 5) may be used. On the other hand, the model described by Burt (Ref. 6) may be used when stable atmospheric conditions exist.

Source configuration evaluations may consider the effluent release point(s) and adjacent or nearby solid structure(s) in conjunction with the individual direction sector (as described in regulatory position 4) in which the downwind receptor of interest is located.

a. Elevated Releases

For effluents exhausted from release points that are higher than twice the height of adjacent solid structures, the effective release height (h_e) is determined (Ref. 4) from:

$$h_e = h_s + h_{pr} - h_t - c \qquad (4)$$

where

- c is the correction for low relative exit velocity (see below);
- h_e is the effective release height;
- h_{pr} is the rise of the plume above the release point, according to Sagendorf (Ref. 4), whose treatment is based on Briggs (Ref. 7);
- h_s is the physical height of the release point (the elevation of the stack base should be assumed to be zero); and
- h_t is the maximum terrain height (above the stack base) between the release point and the point for which the calculation is made (h_t must be greater than or equal to zero).

Note that the effective release height is a function of the distance between the release point and the location where the concentration is being calculated.

When the vertical exit velocity is less than 1.5 times the horizontal windspeed, a correction for downwash is subtracted from Equation (4), according to Gifford (Ref. 8):

$$c = 3(1.5 - W_0/\overline{u})d \qquad (5)$$

where

- c is the downwash correction;
- d is the inside diameter of the stack or other release point;
- $\overline{u}$ is the mean windspeed at the height of release; and
- W_0 is the vertical exit velocity of the plume.

b. Releases Other Than Elevated

For effluents released from points less than the height of adjacent solid structures, a ground-level release should be assumed ($h_e = 0$).

For effluents released from vents or other points at the level of or above adjacent solid structures, but lower than elevated release points, the effluent plume should be considered as an elevated release whenever the vertical exit velocity of the plume, W_o, is at least five times the horizontal windspeed, $\bar{u}$, at the height of release; i.e., as modified from Johnson et al. (Ref. 9):

$$W_o/\bar{u} \geq 5.0 \tag{6}$$

In this case, the release should be evaluated as described in regulatory position 2.a.

If $W_o/\bar{u}$ is less than 1.0 or unknown, a ground-level release should be assumed ($h_e = 0$).

For cases where the ratio of plume exit velocity to horizontal windspeed is between one and five, a mixed release mode should be assumed, in which the plume is considered as an elevated release during a part of the time and as a ground-level release ($h_e = 0$) during the remainder of the time. An entrainment coefficient, E_t, modified from Reference 9, is determined for those cases in which $W_o/\bar{u}$ is between one and five:

$$E_t = 2.58 - 1.58(W_o/\bar{u}) \text{ for } 1 < W_o/\bar{u} \leq 1.5 \tag{7}$$

and

$$E_t = 0.3 - 0.06(W_o/\bar{u}) \text{ for } 1.5 < W_o/\bar{u} \leq 5.0 \tag{8}$$

The release should be considered to occur as an elevated release $100(1 - E_t)$ percent of the time and as a ground release $100E_t$ percent of the time. Each of these cases should then be evaluated separately and the concentration calculated according to the fraction of time each type of release occurs. Windspeeds representative of conditions at the actual release heights should be used for the times when the release is considered to be elevated. Windspeeds measured at the 10-meter level should be used for those times when the effluent plume is considered to be a ground release. If Equation (3) is used, the adjustment described in regulatory position 2.c may be made for the ground release portion of the calculation.

c. Building Wake Correction

For ground-level releases only ($h_e = 0$), an adjustment may be made in Equation (3) that takes into consideration initial mixing of the effluent plume within the building wake. This adjustment, according to Yanskey et al. (Ref. 10), should be in the form of:

$$\Sigma_{zj}(X) = (\sigma_{zj}{}^2(X) + 0.5D_z^2/\pi)^{1/2} \leq \sqrt{3}\sigma_{zj}(X) \tag{9}$$

where

D_z is the maximum adjacent building height either up- or downwind from the release point;

X is the distance from the release point to the receptor, measured from the lee edge of the complex of adjacent buildings;

$\sigma_{zj}(X)$ is the vertical standard deviation of the materials in the plume at distance, X, for atmospheric stability class, j; and

$\Sigma_{zj}(X)$ is the vertical standard deviation of plume material as above, with the correction for additional dispersion within the building wake cavity, restricted by the condition that

$$\Sigma_{zj}(X) = \sqrt{3}\sigma_{zj}(X)$$

when

$$(\sigma_{zj}^2(X) + 0.5D_z^2/\pi)^{1/2} > \sqrt{3}\sigma_{zj}(X).$$

3. Removal Mechanism Considerations

Radioactive decay and dry and wet deposition should be considered in radiological impact evaluations. Acceptable methods of considering these removal mechanisms are described below.

a. Radioactive Decay

For conservative estimates of radioactive decay, an overall half-life of 2.26 days is acceptable for short-lived noble gases and of 8 days for all iodines released to the atmosphere. Alternatively, the actual half-life of each radionuclide may be used. The decay time used should be the calculated time of travel between the source and receptor based on the airflow model used.

b. Dry Deposition

Dry deposition of elemental radioiodines and other particulates and attendant plume depletion should be considered for all releases.

Acceptable plume depletion correction factors and relative deposition rates are presented in Figures 2 through 9. These figures are based on measurements of deposition velocity as a function of windspeed as presented in Reference 11 and on a diffusion-deposition model as presented in Reference 12.

Figures 2 through 5 illustrate an acceptable method for considering plume depletion effects for all distances from the source and atmospheric stability classes for ground and elevated release modes. After a given concentration is calculated by using the models in regulatory position 1, the concentration should be corrected by multiplying by the fraction remaining in the plume, as determined from these figures.

Figures 6 through 9 show acceptable values of relative deposition rate (meters^{-1}) as a function of distance from the source and atmospheric stability for ground and elevated release modes. The relative deposition rate is the deposition rate per unit downwind distance (Ci/sec per meter) divided by the source strength (Ci/sec).

To obtain the relative deposition per unit area (meters^{-2}) at a given point in a given sector, the relative deposition rate must be (1) multiplied by the fraction of the release transported into the sector, determined according to the distribution of wind direction and (2) divided by an appropriate crosswind distance (meters), as discussed below.

Figures 6 through 9 are based on the assumption that the effluent concentration in a given sector is uniform across the sector at a given distance. Therefore, for the straight-line trajectory model, or for any model that assumes uniform concentration across the sector at a given distance, the relative deposition rate should be divided by the arc length of the sector at the point being considered. In addition, for the straight-line trajectory model, the relative deposition rate should be multiplied by the appropriate correction factor discussed in regulatory position 1.c.

For models where concentration at a given distance is not uniform across the sector, the relative deposition at a given point should be calculated as above, but then multiplied by the ratio of the maximum effluent concentration in the sector at the distance being considered to the average concentration across the sector at the same distance.

c. Wet Deposition

For long-term averages, dose calculations considering dry deposition only are not usually changed significantly by the consideration of wet deposition. However, the effects of wet deposition and attendant plume depletion should be considered for plants with predominantly elevated releases and at sites that have a well-defined rainy season corresponding to the grazing season. Consideration of wet deposition effects should include examination of total precipitation, number of hours of precipitation, rainfall rate distributions, and the precipitation wind rose. If the precipitation data indicate that wet deposition may be significant, washout rates and attendant plume depletion should be calculated in accordance with the relationships identified by Engelmann (Ref. 13).

d. Deposition Over Water

For dispersion over small bodies of water, deposition may be assumed to occur at the same rate as over land. For calculations involving radionuclide transport over large bodies of water, deposition should be considered on a case-by-case basis.

4. Meteorological Data for Models

Sufficient meteorological information should be obtained to characterize transport processes (i.e., airflow trajectory, diffusion conditions, deposition characteristics) out to a distance of 50 miles (approximately 80,000 meters) from the plant. The primary source of meteorological information should be the onsite meteorological program (see Regulatory Guide 1.23, Ref. 14). Other sources should include nearby National Weather Service (NWS) stations, other well-maintained meteorological facilities (e.g., other nuclear facilities, universities, or private meteorological programs), and satellite facilities.

Adequate characterization of transport processes within 50 miles of the plant may include examination of meteorological data from stations further than 50 miles when this information can provide additional clarification of the mesoscale transport processes. To augment the assessment of atmospheric transport to distances of 50 miles from the plant, the following regional meteorological data, based on periods of record specified in Regulatory Guide 4.2 (Ref. 15), from as many relevant stations as practicable should be used:

a. Windspeed

b. Wind direction

c. Atmospheric stability

d. Mixing height

e. Precipitation

For input to variable trajectory atmospheric transport models, measured hourly values of windspeed should be used. Calms* should be assigned a windspeed of one-half of the appropriate starting speed, as described in the footnote, for instruments conforming to the recommendations or intent of Regulatory Guide 1.23 (Ref. 14). Otherwise, a windspeed of 0.1 meter/second should be assigned to calms. Hourly wind directions should be classed into at least the 16 compass point sectors (i.e., 22.5-degree sectors, centered on true north, north-northeast, etc.) according to measured values averaged over the time interval.

For input to the constant mean wind direction model, windspeed data should be presented as (1) hourly measured values or (2) windspeed classes divided in accordance with the Beaufort wind scale or other suitable class division (e.g., a greater number of light windspeed classes should be used for sites with high frequencies of light winds). Wind directions should be divided into the 16 compass directions (22.5-degree sectors, centered on true north, north-northeast, etc.). If joint frequency distributions of wind direction and speed by atmospheric stability class, rather than hourly values, are used in this model, calms* should be assigned to wind directions in proportion to the directional distribution within an atmospheric stability class of the lowest noncalm windspeed class. If hourly data are used, calms should be assigned to the recorded wind direction averaged over the time interval. The windspeed to be assumed for calms is one-half of the starting speed of the vane or anemometer, whichever is higher, for instruments conforming to the recommendations or intent of Regulatory Guide 1.23. Otherwise, the windspeed to be assumed for calms is 0.1 meter/second.

Atmospheric stability should be determined by vertical temperature difference (ΔT) between the release point and the 10-meter level, or by other well-documented parameters that have been substantiated by diffusion data. Acceptable stability classes are given in Reference 14.

Appropriate time periods for meteorological data utilization should be based on constancy of the source term (rate of release) and potential availability of the receptor (e.g., man or cow). If emissions are continuous, annual data summaries should be used. If releases are intermittent, consideration should be given to frequency and duration of release. If emissions are

*Calms are defined as hourly average windspeeds below the starting speed of the vane or anemometer, whichever is higher.

infrequent and of short duration, atmospheric dispersion models and meteorological data applicable to the time of release should be considered. Use of annual average conditions for consideration of intermittent releases will be acceptable only if it is established that releases will be random in time. Otherwise the method of evaluation of intermittent releases should follow the methodology outlined in Section 2.3.4 of NUREG-75/087 (Ref. 16). This method uses an appropriate χ/Q probability level, as well as the annual average χ/Q, for the direction and point of interest being evaluated to provide the basis for adjustments reflecting more adverse diffusion conditions than indicated by the annual average. These adjustments are applied to the annual average χ/Q and D/Q for the total number of hours associated with intermittent releases per year. Detailed information for this calculation is given by Sagendorf and Goll (Ref. 17). However, if intermittent releases are limited by technical specifications to periods when atmospheric conditions are more favorable than average for the site, annual average data and annual average dispersion models could be used. For calculations of doses through ingestion pathways, particularly through the cow-milk pathway, meteorological data for only the grazing or growing season should be used.

D. IMPLEMENTATION

The purpose of this section is to provide information to license applicants and licensees regarding the NRC staff's plans for implementing this regulatory guide.

This guide reflects current NRC staff practice. Therefore, except in those cases in which the license applicant or licensee proposes an acceptable alternative method, the method described herein for complying with specified portions of the Commission's regulations will continue to be used in the evaluation of submittals for operating license or construction permit applications until this guide is revised as a result of suggestions from the public or additional staff review.

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Vertical Dispersion Coefficients

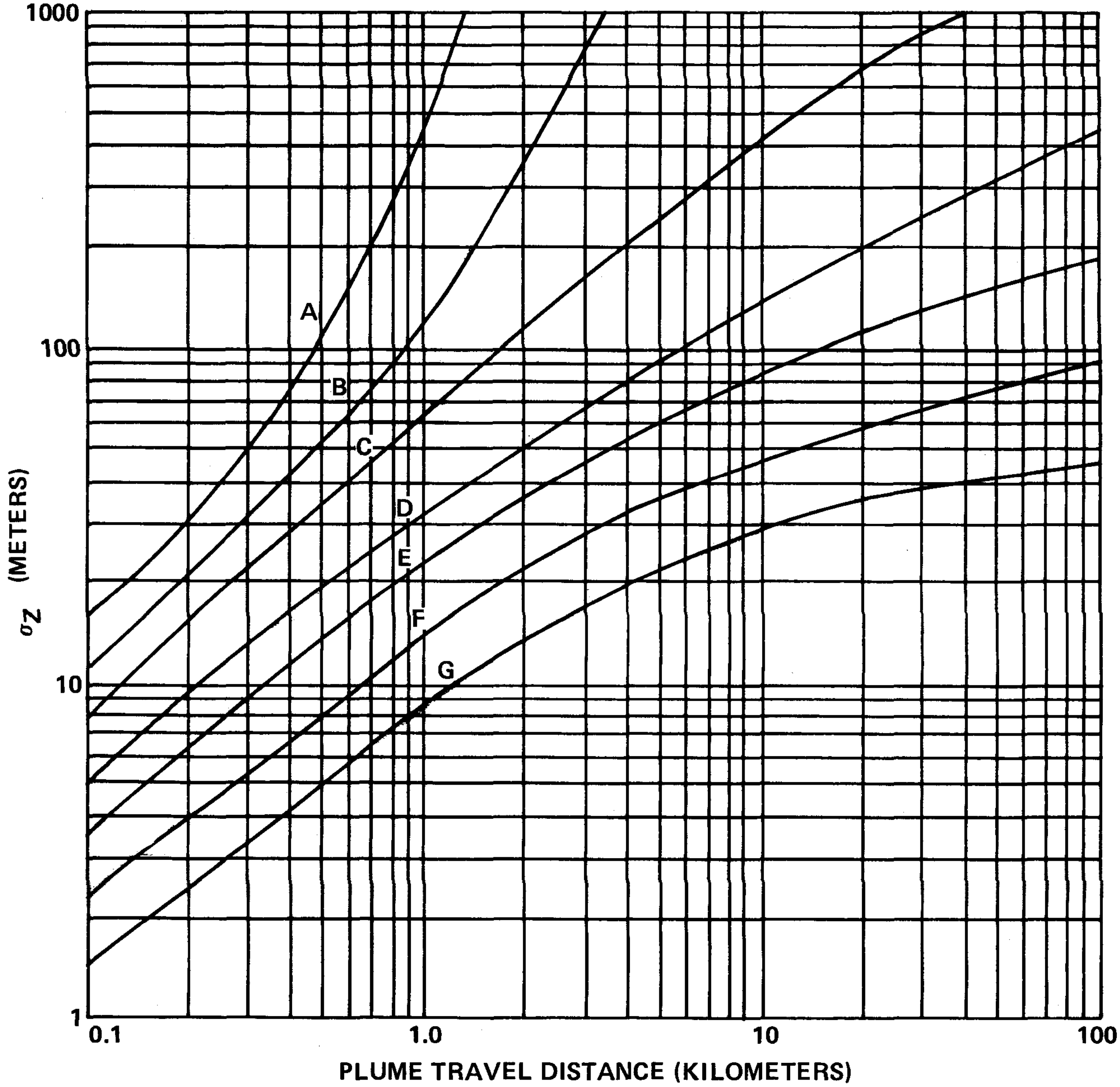

Figure 1. Vertical Standard Deviation of Material in a Plume (Letters denote Pasquill Stability Class)

NOTE: THESE ARE STANDARD RELATIONSHIPS AND MAY HAVE TO BE MODIFIED FOR CERTAIN TYPES OF TERRAIN AND/OR CLIMATIC CONDITIONS (E.G., VALLEY, DESERT, OVER WATER).

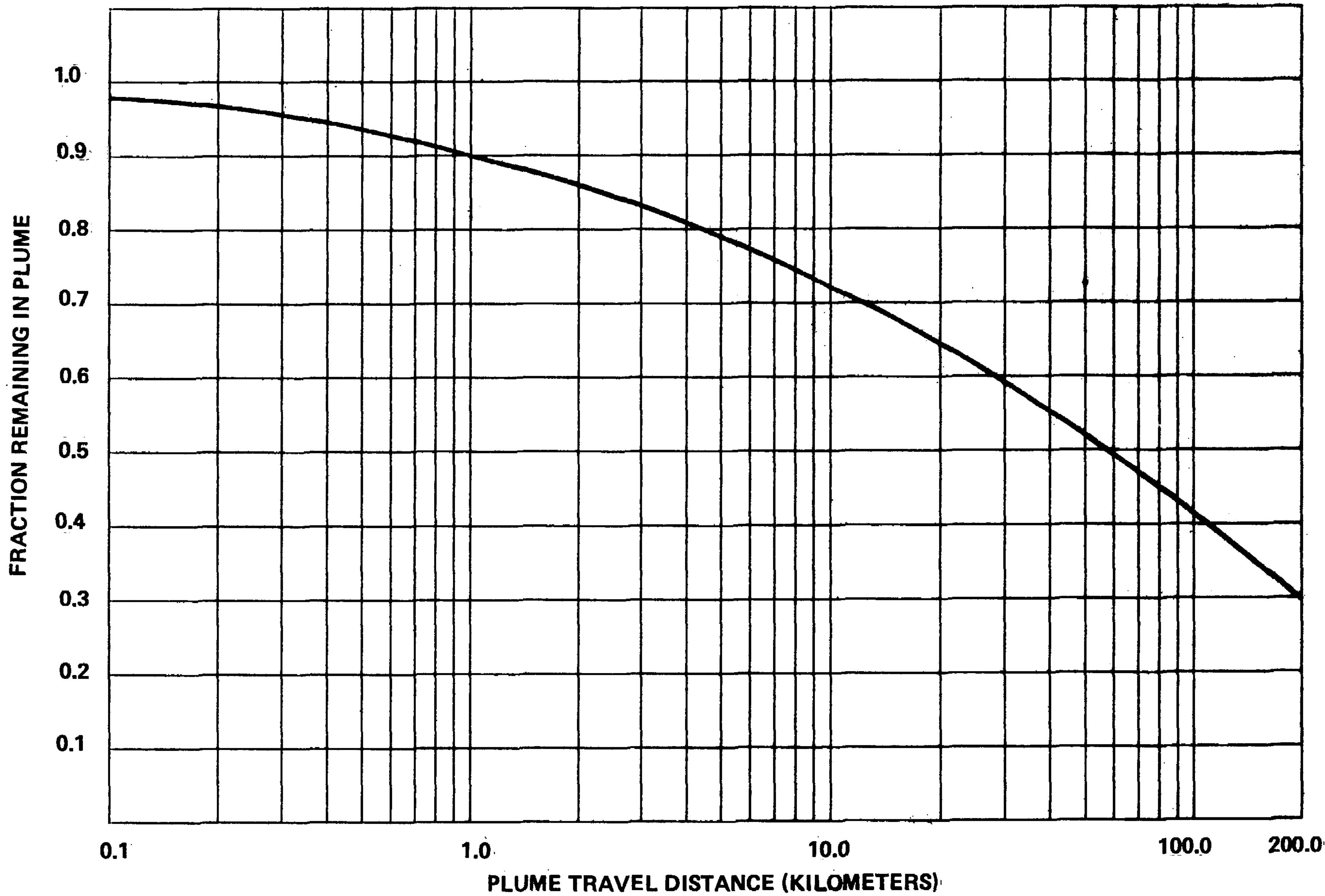

Figure 2. Plume Depletion Effect for Ground-Level Releases (All Atmospheric Stability Classes)

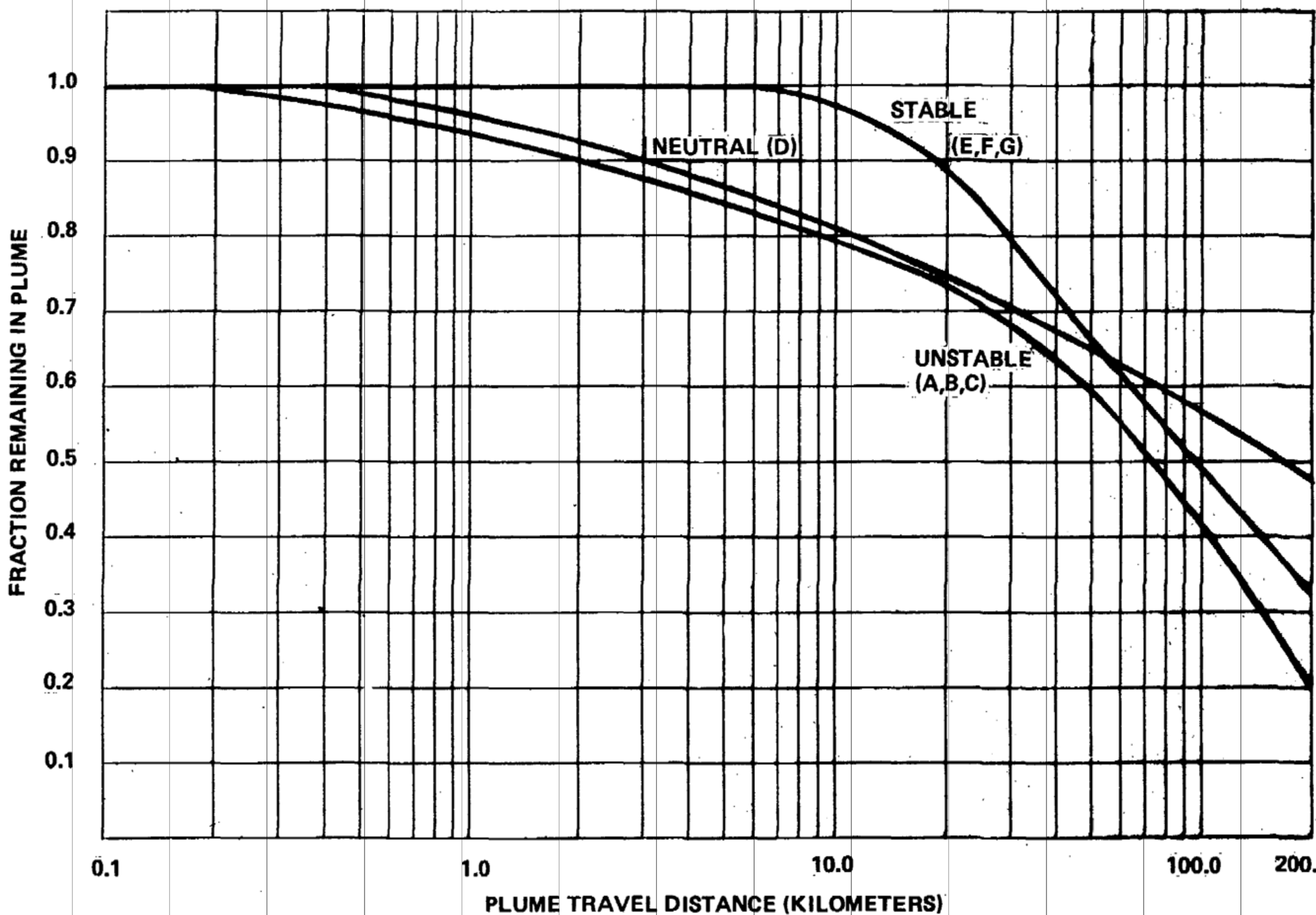

Figure 3. Plume Depletion Effect for 30-m Releases (Letters denote Pasquill Stability Class).

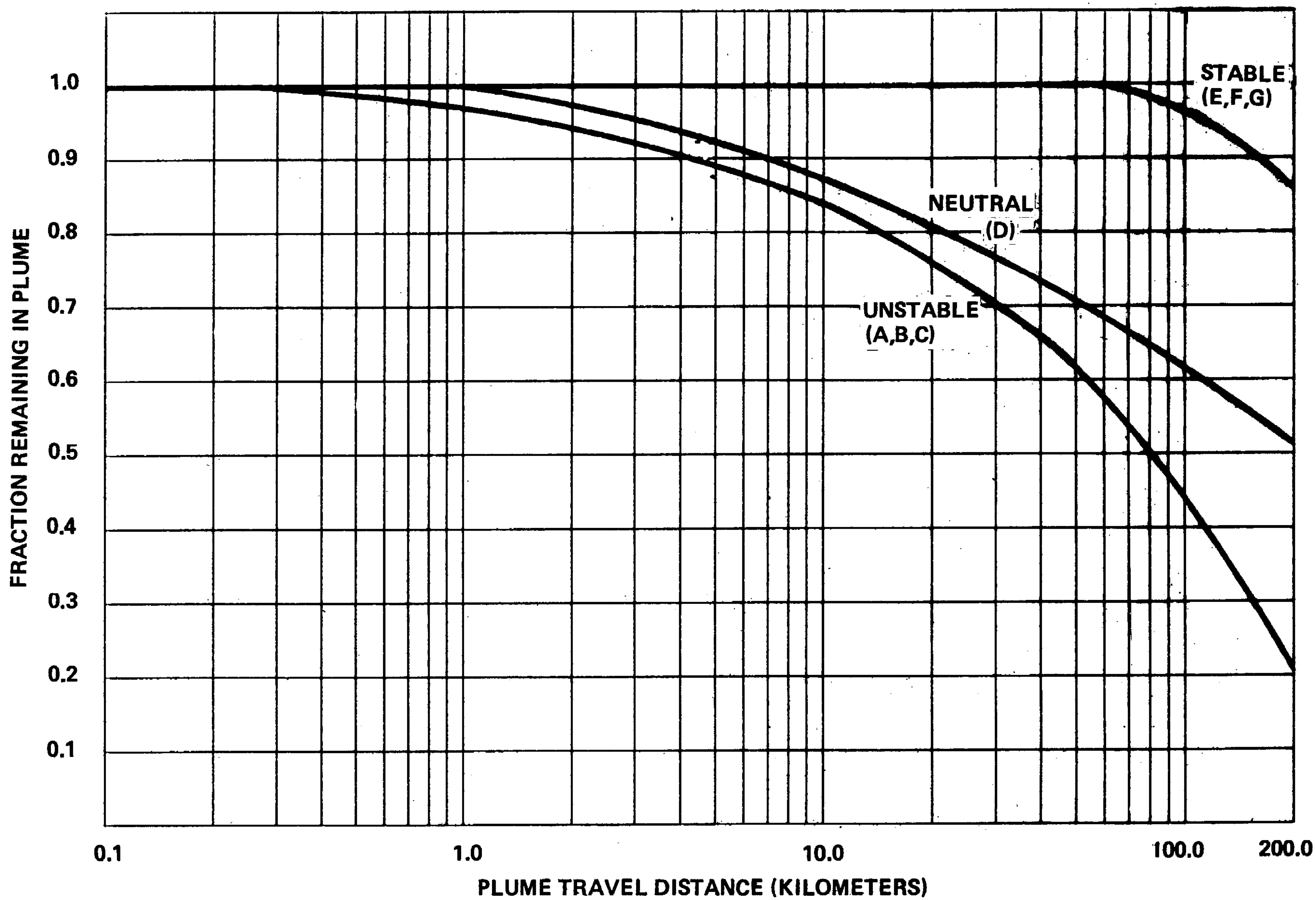

Figure 4. Plume Depletion Effect for 60-m Releases (Letters denote Pasquill Stability Class)

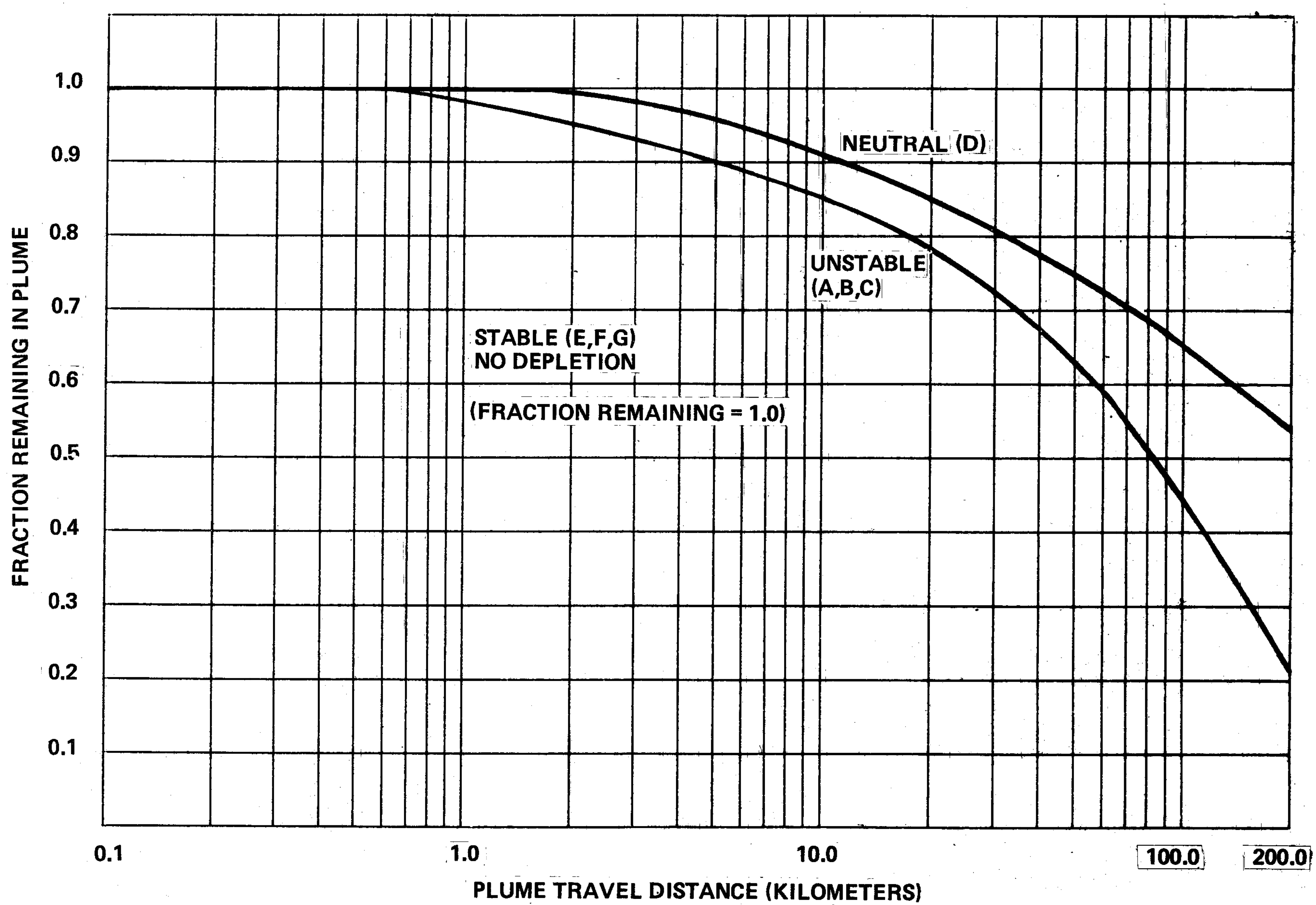

Figure 5. Plume Depletion Effect for 100-m Releases (Letters denote Pasquill Stability Class)

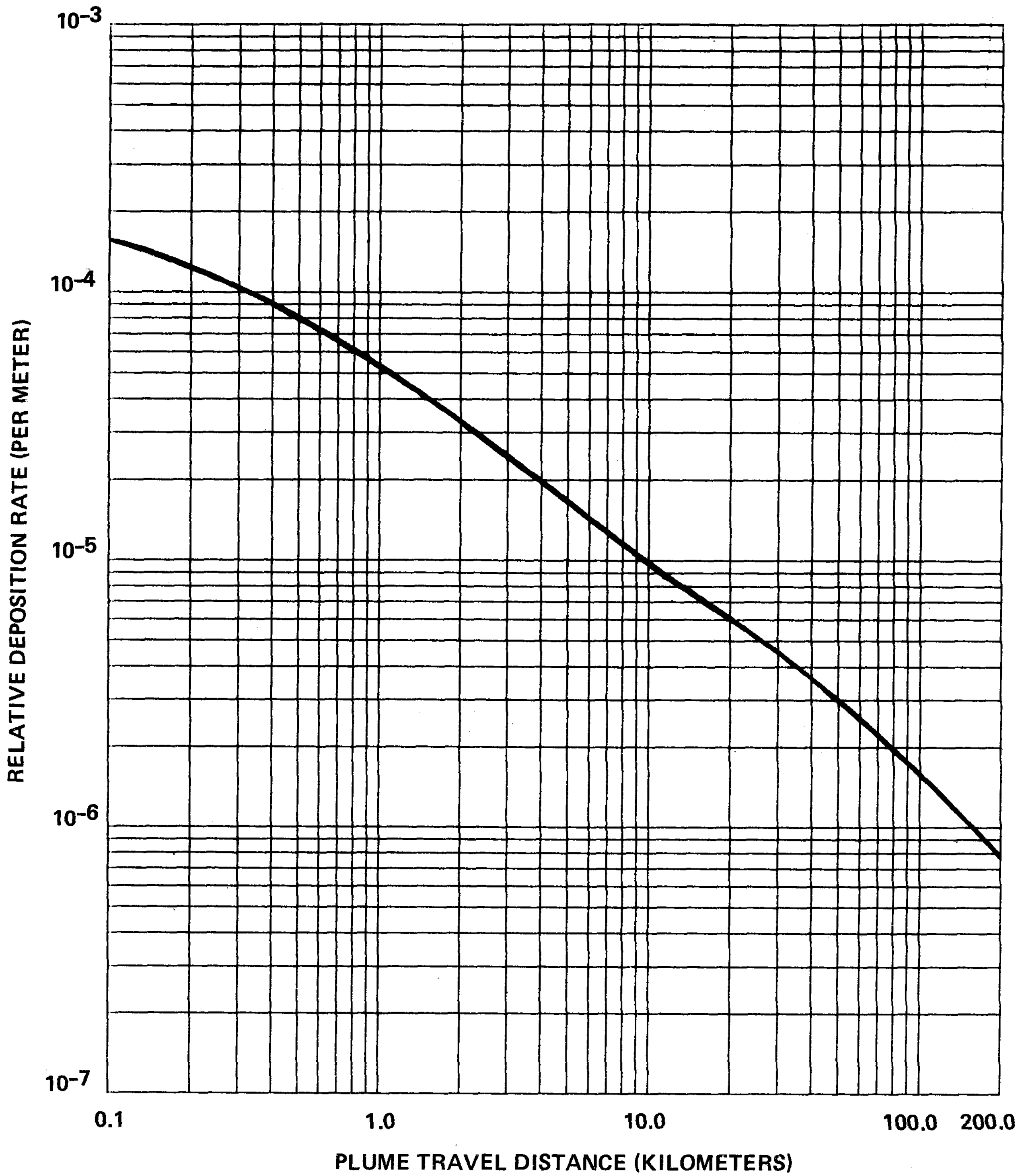

Figure 6. Relative Deposition for Ground-Level Releases (All Atmospheric Stability Classes)

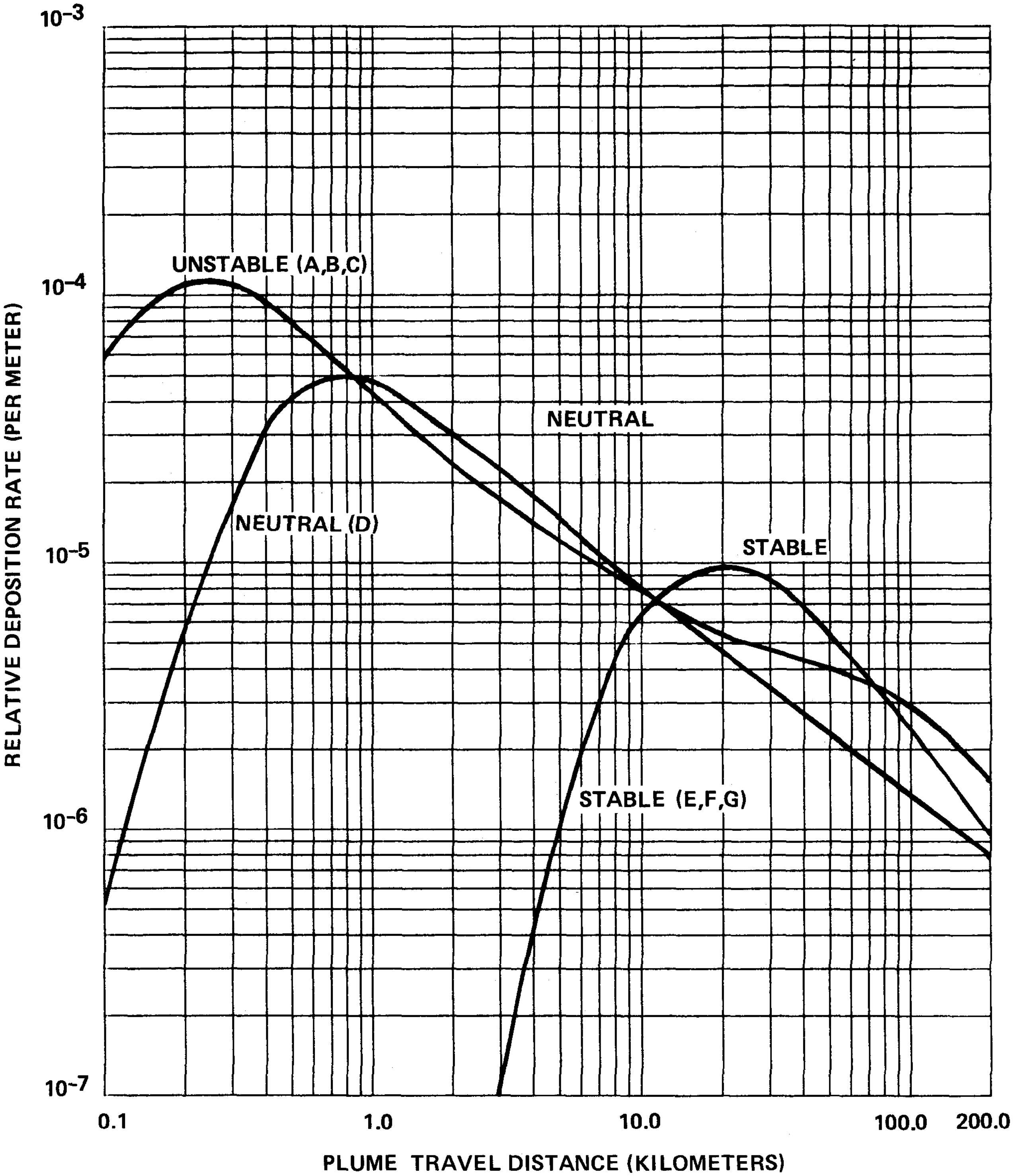

Figure 7. Relative Deposition for 30-m Releases (Letters denote Pasquill Stability Class)

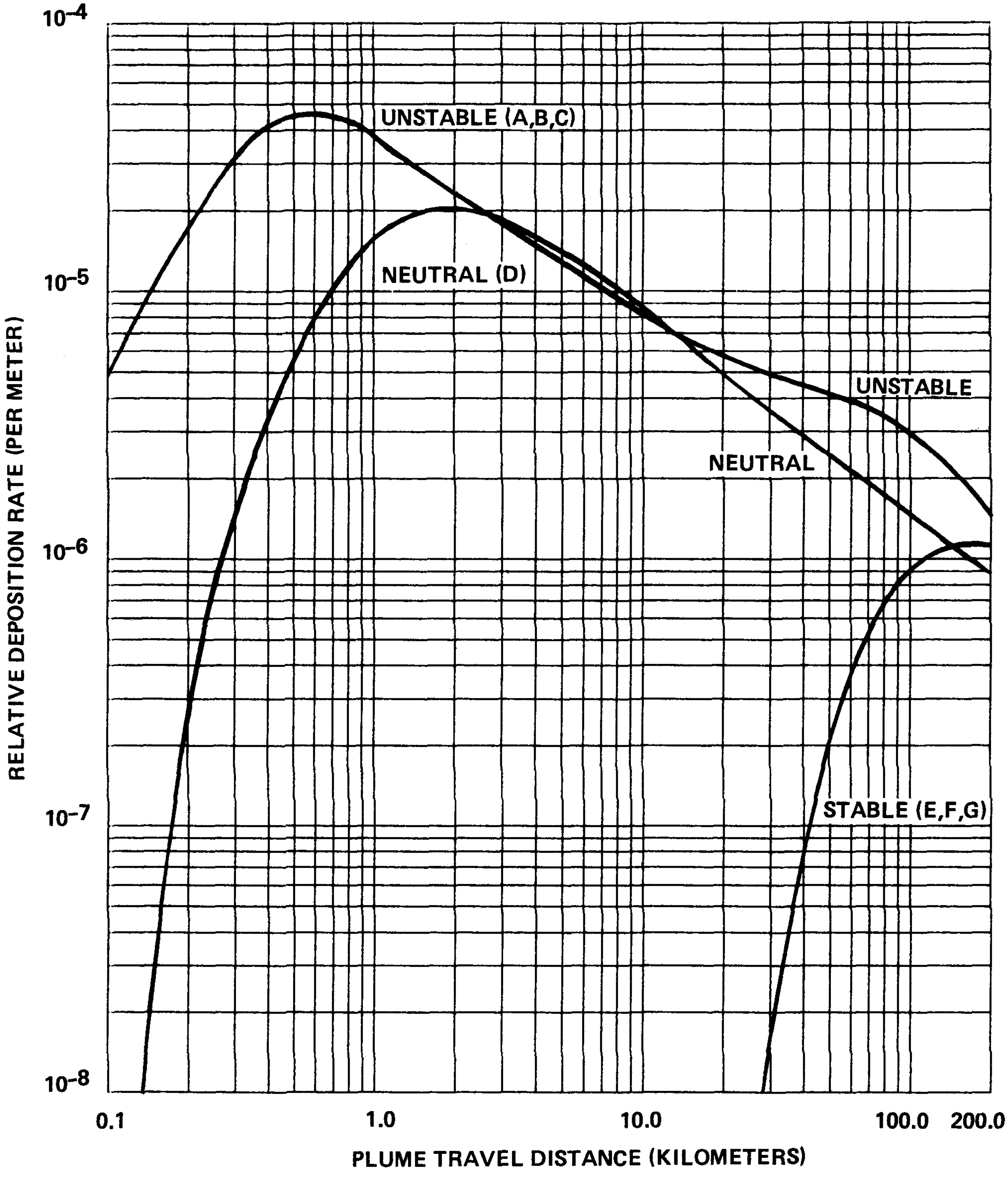

Figure 8. Relative Deposition for 60-m Releases (Letters denote Pasquill Stability Class)

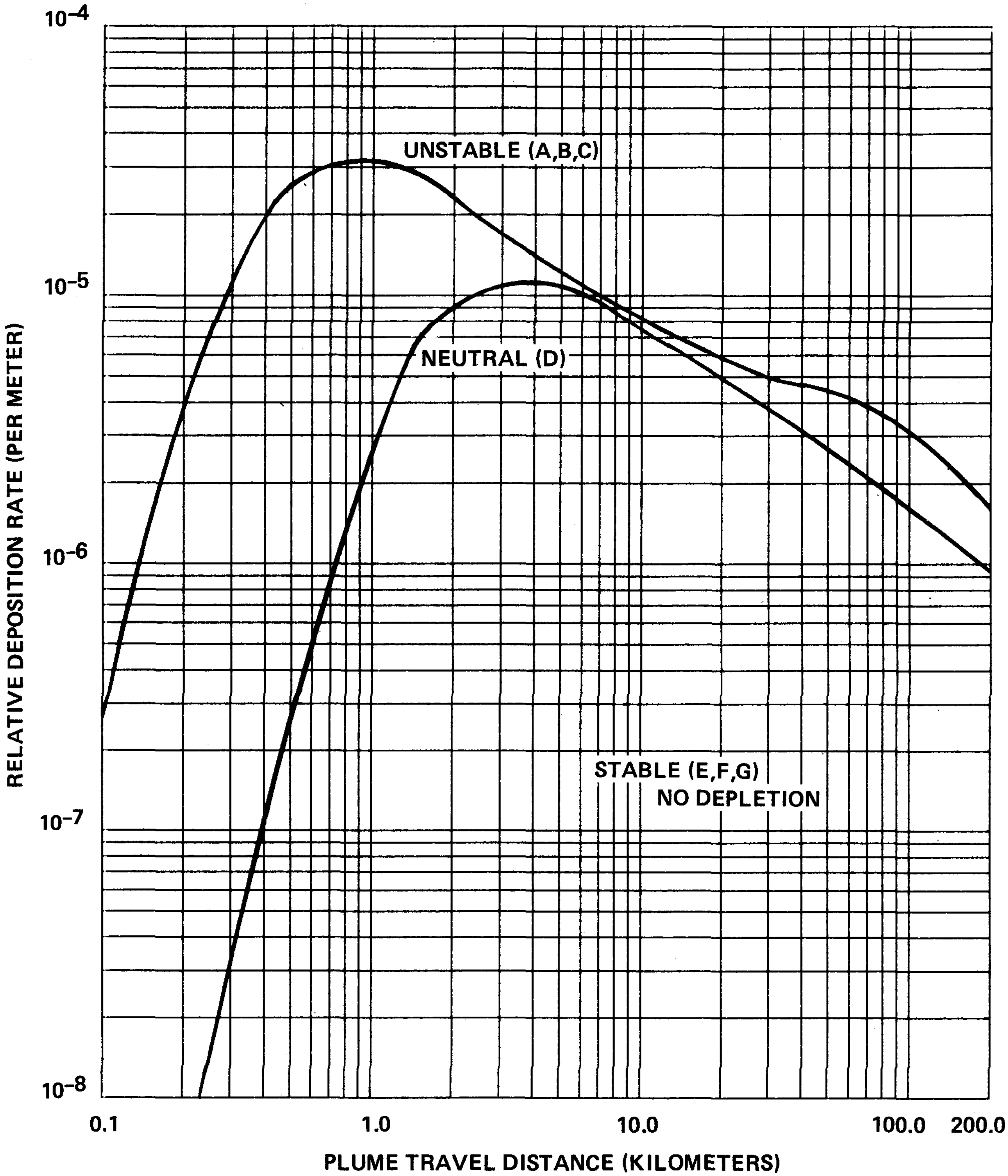

Figure 9. Relative Deposition for 100-m Releases (Letters denote Pasquill Stability Class)