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U.S. ATOMIC ENERGY COMMISSION

REGULATORY GUIDE

DIRECTORATE OF REGULATORY STANDARDS

REGULATORY GUIDE 1.3

ASSUMPTIONS USED FOR EVALUATING THE POTENTIAL RADIOLOGICAL CONSEQUENCES OF A LOSS OF COOLANT ACCIDENT FOR BOILING WATER REACTORS

A. INTRODUCTION

Section 50.34 of 10 CFR Part 50 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 operation of the facility. The design basis loss of coolant accident (LOCA) is one of the postulated accidents used to evaluate the adequacy of these structures, systems, and components with respect to the public health and safety. This guide gives acceptable assumptions that may be used in evaluating the radiological consequences of this accident for a boiling water reactor. In some cases, unusual site characteristics, plant design features, or other factors may require different assumptions which will be considered on an individual case basis. The Advisory Committee on Reactor Safeguards has been consulted concerning this guide and has concurred in the regulatory position.

B. DISCUSSION

After reviewing a number of applications for construction permits and operating licenses for boiling water power reactors, the AEC Regulatory staff has developed a number of appropriately conservative assumptions, based on engineering judgment and on applicable experimental results from safety research programs conducted by the AEC and the nuclear industry, that are used to evaluate calculations of the diological consequences of various postulated accidents.

This guide lists acceptable assumptions that may be used to evaluate the design basis LOCA of a Boiling Water Reactor (BWR). It should be shown that the offsite dose consequences will be within the guidelines of 10 CFR Part 100. (During the construction permit review, guideline exposures of 20 rem whole body and 150 rem thyroid should be used rather than the values given in § 100.11 in order to allow for (a) uncertainties in final design details and meteorology or (b) new data and calculational techniques that might influence the final design of engineered safety features or the dose reduction factors allowed for these features.)

C. REGULATORY POSITION

1. The assumptions related to the release of radioactive material from the fuel and containment are as follows:

a. Twenty-five percent of the equilibrium radioactive iodine inventory developed from maximum full power operation of the core should be assumed to be immediately available for leakage from the primary reactor containment. Ninety-one percent of this 25 percent is to be assumed to be in the form of elemental iodine, 5 percent of this 25 percent in the form of particulate iodine, and 4 percent of this 25 percent in the form of organic iodides.

b. One hundred percent of the equilibrium radioactive noble gas inventory developed from maximum full power operation of the core should be assumed to be immediately available for leakage from the reactor containment.

c. The effects of radiological decay during holdup in the containment or other buildings should be taken into account.

d. The reduction in the amount of radioactive material available for leakage to the environment by containment sprays, recirculating filter systems, or other engineered safety features may be taken into account, but the amount of reduction in concentration of radioactive materials should be evaluated on an individual case basis.

e. The primary containment should be assumed to leak at the leak rate incorporated or to be incorporated in the technical specifications for the duration of the

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The guides are issued in the following ten broad divisions:

1. Power Reactors
2. Research and Test Reactors
3. Fuels and Materials Facilities
4. Environmental and Siting
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9. Antitrust Review
10. General

accident.[1] The leakage should be assumed to pass directly to the emergency exhaust system without mixing[2] in the surrounding reactor building atmosphere and should then be assumed to be released as an elevated plume for those facilities with stacks.[3]

f. No credit should be given for retention of iodine in the suppression pool.

2. Acceptable assumptions for atmospheric diffusion and dose conversion are:

a. Elevated releases should be considered to be at a height equal to no more than the actual stack height. Certain site dependent conditions may exist, such as surrounding elevated topography or nearby structures which will have the effect of reducing the actual stack height. The degree of stack height reduction should be evaluated on an individual case basis. Also, special meteorological and geographical conditions may exist which can contribute to greater ground level concentrations in the immediate neighborhood of a stack. For example, fumigation should always be assumed to occur; however, the length of time that a fumigation condition exists is strongly dependent on geographical and seasonal factors and should be evaluated on a case-by-case basis.[4] (See Figures 1A through 1D for atmospheric diffusion factors for an elevated release with fumigation.)

b. No correction should be made for depletion of the effluent plume of radioactive iodine due to deposition on the ground, or for the radiological decay of iodine in transit.

c. For the first 8 hours, the breathing rate of persons offsite should be assumed to be 3.47×10^{-4} cubic meters per second. From 8 to 24 hours following the accident, the breathing rate should be assumed to be 1.75×10^{-4} cubic meters per second. After that until the end of the accident, the rate should be assumed to be 2.32×10^{-4} cubic meters per second. (These values were developed from the average daily breathing rate [2×10^7 cm^3/day] assumed in the report of ICRP, Committee II-1959.)

d. The iodine dose conversion factors are given in ICRP Publication 2, Report of Committee II, "Permissible Dose for Internal Radiation," 1959.

e. External whole body doses should be calculated using "Infinite Cloud" assumptions, i.e., the dimensions of the cloud are assumed to be large compared to the distance that the gamma rays and beta particles travel. "Such a cloud would be considered an infinite cloud for a receptor at the center because any additional [gamma and] beta emitting material beyond the cloud dimensions would not alter the flux of [gamma rays and] beta particles to the receptor" (Meteorology and Atomic Energy, Section 7.4.1.1–editorial additions made so that gamma and beta emitting material could be considered). Under these conditions the rate of energy absorption per unit volume is equal to the rate of energy released per unit volume. For an infinite uniform cloud containing χ curies of beta radioactivity per cubic meter the beta dose in air at the cloud center is:

$$_{\beta}D'_{\infty} = 0.457\ \bar{E}_{\beta}\chi$$

The surface body dose rate from beta emitters in the infinite cloud can be approximated as being one-half this amount (i.e., $_{\beta}D'_{\infty} = 0.23\ \bar{E}_{\beta}\chi$).

For gamma emitting material the dose rate in air at the cloud center is:

$$_{\gamma}D'_{\infty} = 0.507\ \bar{E}_{\gamma}\chi$$

From a semi-infinite cloud, the gamma dose rate in air is:

$$_{\gamma}D'_{\infty} = 0.25\ \bar{E}_{\gamma}\chi$$

Where

$_{\beta}D'_{\infty}$ = beta dose rate from an infinite cloud (rad/sec)
$_{\gamma}D'_{\infty}$ = gamma dose rate from an infinite cloud (rad/sec)
$\bar{E}_{\beta}$ = average beta energy per disintegration (Mev/dis)
$\bar{E}_{\gamma}$ = average gamma energy per disintegration (Mev/dis)
χ = concentration of beta or gamma emitting isotope in the cloud (curie/m^3)

f. The following specific assumptions are acceptable with respect to the radioactive cloud dose calculations:

(1) The dose at any distance from the reactor should be calculated based on the maximum concentration in the plume at that distance taking into account specific meteorological, topographical, and other characteristics which may affect the maximum plume concentration. These site related characteristics

[1] The effect on containment leakage under accident conditions of features provided to reduce the leakage of radioactive materials from the containment will be evaluated on an individual case basis.

[2] In some cases, credit for mixing will be allowed; however, the amount of credit allowed will be evaluated on an individual case basis.

[3] Credit for an elevated release should be given only if the point of release is (1) more than two and one-half times the height of any structure close enough to affect the dispersion of the plume, or (2) located far enough from any structure which could have an effect on the dispersion of the plume. For those BWR's without stacks the atmospheric diffusion factors assuming ground level release given in section 2.h. should be used to determine site acceptability.

[4] For sites located more than 2 miles from large bodies of water such as oceans or one of the Great Lakes, a fumigation condition should be assumed to exist at the time of the accident and continue for one-half hour. For sites located less than 2 miles from large bodies of water, a fumigation condition should be assumed to exist at the time of the accident and continue for 4 hours.

must be evaluated on an individual case basis. In the case of beta radiation, the receptor is assumed to be exposed to an infinite cloud at the maximum ground level concentration at that distance from the reactor. In the case of gamma radiation, the receptor is assumed to be exposed to only one-half the cloud owing to the presence of the ground. The maximum cloud concentration always should be assumed to be at ground level.

(2) The appropriate average beta and gamma energies emitted per disintegration, as given in the Table of Isotopes, Sixth Edition, by C. M. Lederer, J. M. Hollander, I. Perlman; University of California, Berkeley; Lawrence Radiation Laboratory; should be used.

g. For BWR's with stacks the atmospheric diffusion model should be as follows:

(1) The basic equation for atmospheric diffusion from an elevated release is:

$$\chi/Q = \frac{\exp(-h^2/2\sigma_z^2)}{\pi u \sigma_y \sigma_z}$$

Where

- χ = the short term average centerline value of the ground level concentration (curie/meter^3)
- Q = amount of material released (curie/sec)
- u = windspeed (meter/sec)
- σ_y = the horizontal standard deviation of the plume (meters) [See Figure V-1, Page 48, *Nuclear Safety,* June 1961, Volume 2, Number 4, "Use of Routine Meteorological Observations for Estimating Atmospheric Dispersion," F. A. Gifford, Jr.]
- σ_z = the vertical standard deviation of the plume (meters) [See Figure V-2, Page 48, *Nuclear Safety*, June 1961, Volume 2, Number 4, "Use of Routine Meteorological Observations for Estimating Atmospheric Dispersion," F. A. Gifford, Jr.]
- h = effective height of release (meters)

(2) For time periods of greater than 8 hours the plume from an elevated release should be assumed to meander and spread uniformly over a 22.5° sector. The resultant equation is:

$$\chi/Q = \frac{2.032 \exp(-h^2/2\sigma_z^2)}{\sigma_z u x}$$

Where

- x = distance from the release point (meters); other variables are as given in g(1).

(3) The atmospheric diffusion model[5] for an elevated release as a function of the distance from the reactor, is based on the information in the table below.

Time Following Accident	Atmospheric Conditions
0-8 hours	*See Figure 1(A)* Envelope of Pasquill diffusion categories based on Figure A7 Meteorology and Atomic Energy-1968, assuming various stack heights; windspeed 1 meter/sec; uniform direction.
8-24 hours	*See Figure 1(B)* Envelope of Pasquill diffusion categories; windspeed 1 meter/sec; variable direction within a 22.5° sector.
1-4 days	*See Figure 1(C)* Envelope of Pasquill diffusion categories with the following relationship used to represent maximum plume concentrations as a function of distance:

Atmospheric Condition Case 1
- 40% Pasquill A
- 60% Pasquill C

Atmospheric Condition Case 2
- 50% Pasquill C
- 50% Pasquill D

Atmospheric Condition Case 3
- 33.3% Pasquill C
- 33.3% Pasquill D
- 33.3% Pasquill E

Atmospheric Condition Case 4
- 33.3% Pasquill D
- 33.3% Pasquill E
- 33.3% Pasquill F

Atmospheric Condition Case 5
- 50% Pasquill D
- 50% Pasquill F

wind speed variable (Pasquill Types A, B, E, and F windspeed 2 meter/sec; Pasquill Types C and D windspeed 3 meter/sec); variable direction within a 22.5° sector.

4-30 days	*See Figure 1(D)* Same diffusion relations as given above; windspeed variable dependent on Pasquill Type used; wind direction 33.3% frequency in a 22.5° sector.

[5] This model should be used until adequate site meteorological data are obtained. In some cases, available information, such as meteorology, topography and geographical location, may dictate the use of a more restrictive model to insure a conservative estimate of potential offsite exposures.

h. For BWR's without stacks the atmospheric diffusion model[6] should be as follows:

(1) The 0-8 hour ground level release concentrations may be reduced by a factor ranging from one to a maximum of three (see Figure 2) for additional dispersion produced by the turbulent wake of the reactor building in calculating potential exposures. The volumetric building wake correction factor, as defined in section 3-3.5.2 of Meteorology and Atomic Energy 1968, should be used only in the 0-8 hour period; it is used with a shape factor of 1/2 and the minimum cross-sectional area of the reactor building only.

(2) The basic equation for atmospheric diffusion from a ground level point source is:

$$\chi/Q = \frac{1}{\pi u \sigma_y \sigma_z}$$

Where

- χ = the short term average centerline value of the ground level concentration (curie/meter^3)
- Q = amount of material released (curie/sec)
- u = windspeed (meter/sec)
- σ_y = the horizontal standard deviation of the plume (meters) [See Figure V-1, Page 48, *Nuclear Safety,* June 1961, Volume 2, Number 4, "Use of Routine Meteorological Observations for Estimating Atmospheric Dispersion," F. A. Gifford, Jr.]
- σ_z = the vertical standard deviation of the plume (meters) [See Figure V-2, Page 48, *Nuclear Safety*, June 1961, Volume 2, Number 4, "Use of Routine Meteorological Observations for Estimating Atmospheric Dispersion," F. A. Gifford, Jr.]

(3) For time periods of greater than 8 hours the plume should be assumed to meander and spread uniformly over a 22.5° sector. The resultant equation is:

$$\chi/Q = \frac{2.032}{\sigma_z u x}$$

Where

- x = distance from point of release to the receptor; other variables are as given in h(2).

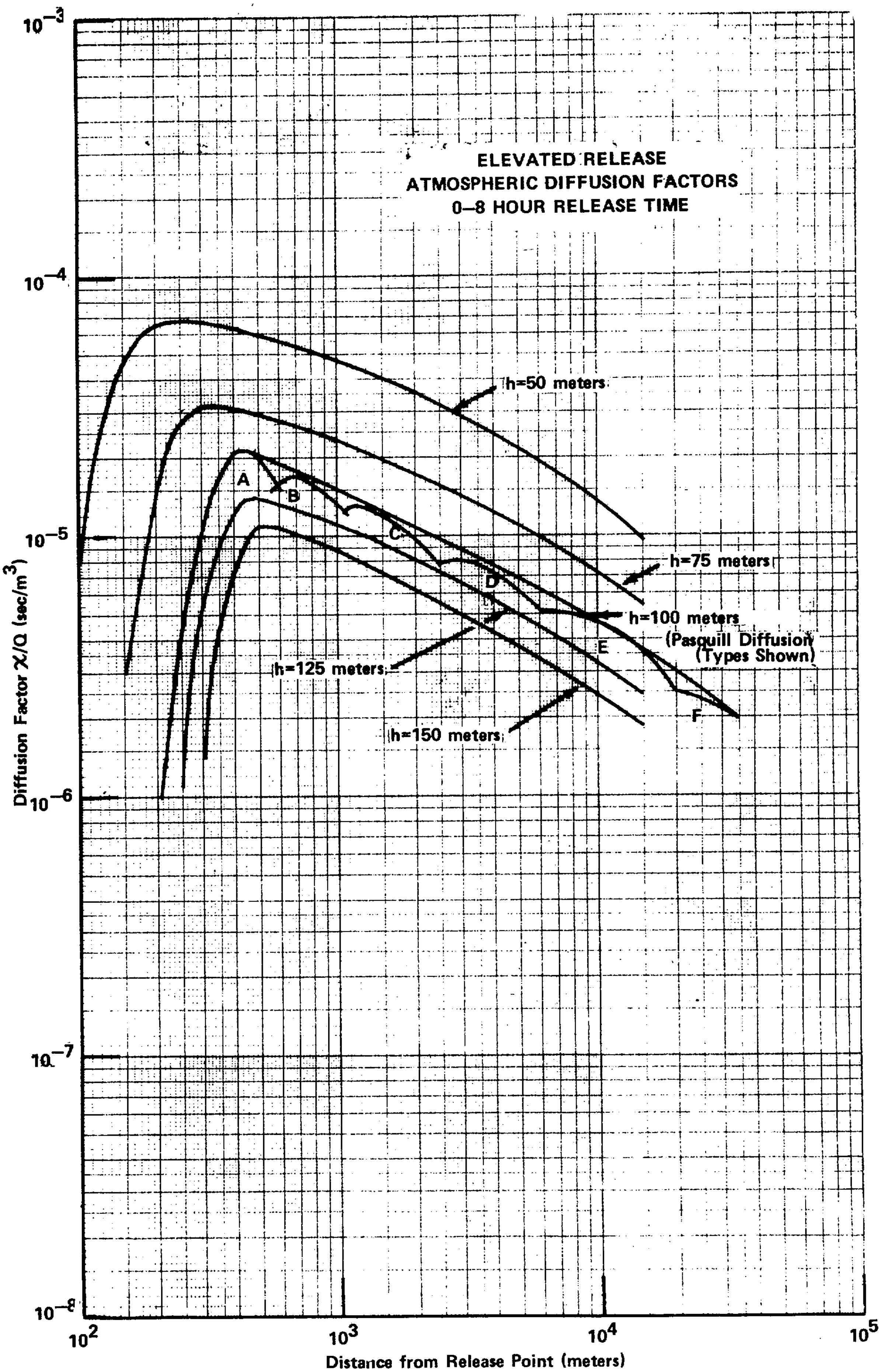
(4) The atmospheric diffusion model for ground level releases is based on the information in the table below.

Time Following Accident	Atmospheric Conditions
0-8 hours	Pasquill Type F, windspeed 1 meter/sec, uniform direction
8-24 hours	Pasquill Type F, windspeed 1 meter/sec, variable direction within a 22.5° sector
1-4 days	(a) 40% Pasquill Type D, windspeed 3 meter/sec (b) 60% Pasquill Type F, windspeed 2 meter/sec (c) wind direction variable within a 22.5° sector
4-30 days	(a) 33.3% Pasquill Type C, windspeed 3 meter/sec (b) 33.3% Pasquill Type D, windspeed 3 meter/sec (c) 33.3% Pasquill Type F, windspeed 2 meter/sec (d) Wind direction 33.3% frequency in a 22.5° sector

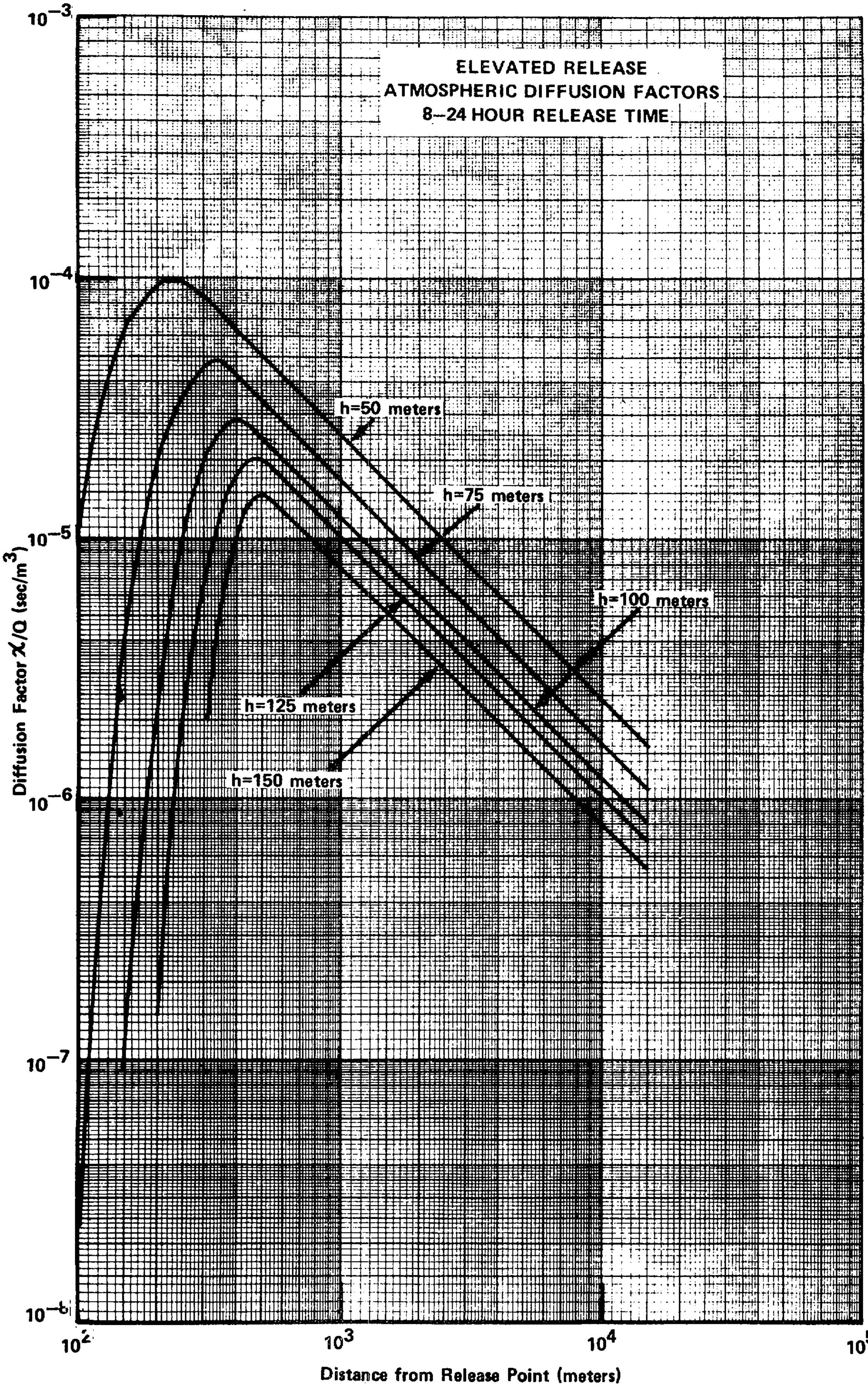
(5) Figures 3A and 3B give the ground level release atmospheric diffusion factors based on the parameters given in h(4).

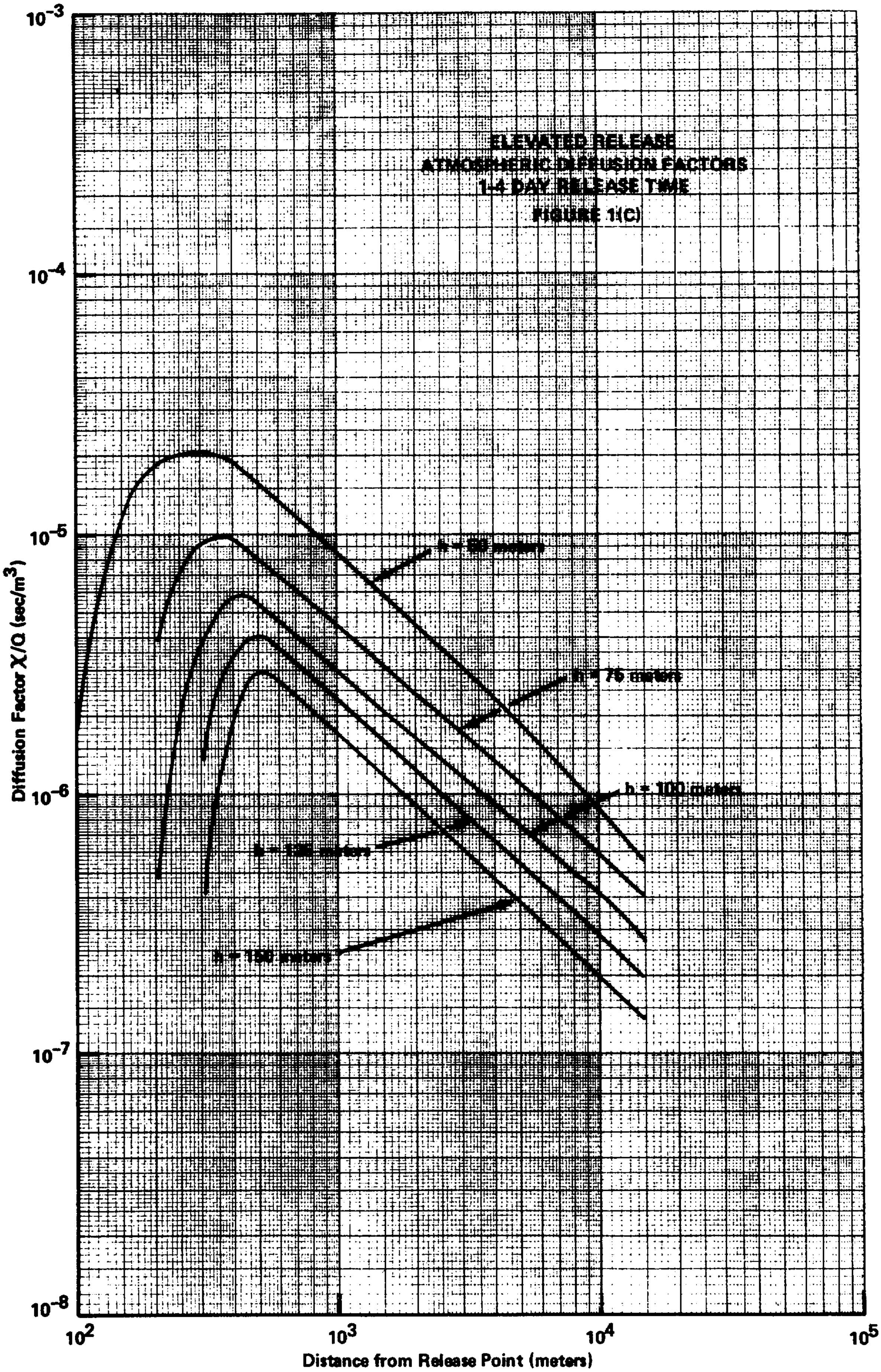
D. IMPLEMENTATION

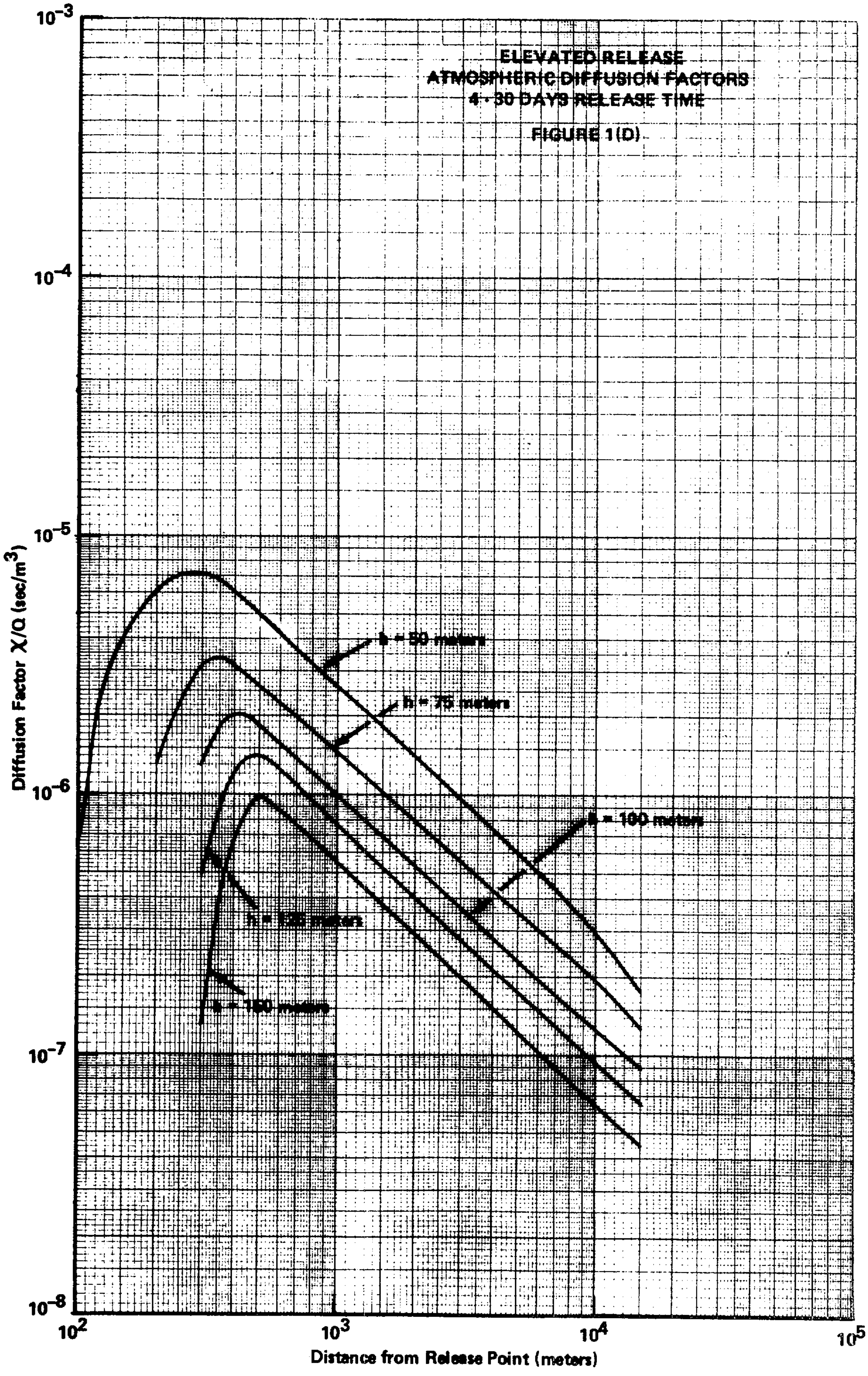
The purpose of the revision (indicated by a line in the margin) to this guide is to reflect current Regulatory staff practice in the review of construction permit applications, and the revised guide, therefore, is effective immediately.



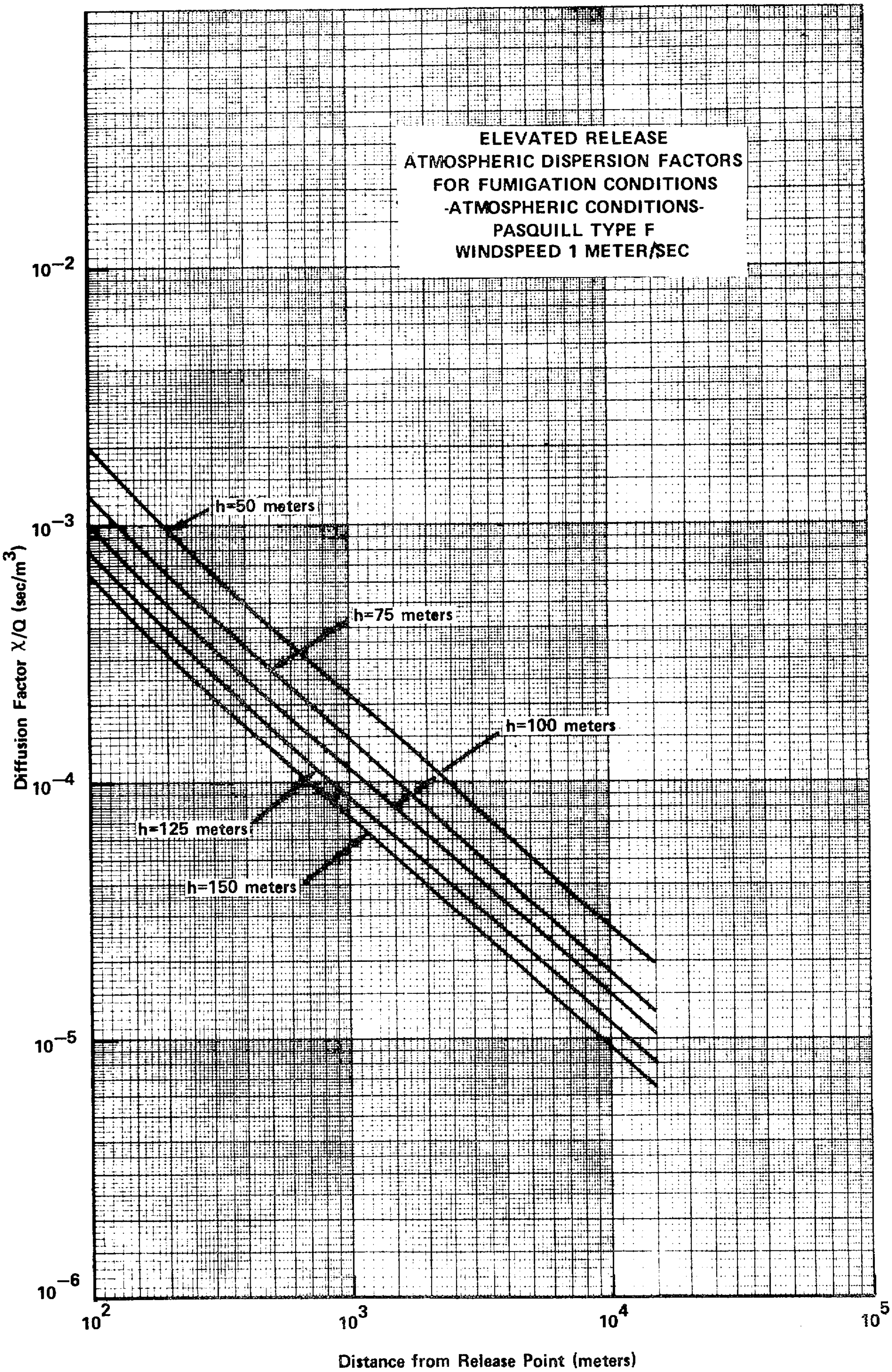
ELEVATED RELEASE
ATMOSPHERIC DIFFUSION FACTORS
0–8 HOUR RELEASE TIME
h=50 meters
h=75 meters
h=100 meters
(Pasquill Diffusion
(Types Shown)
h=125 meters
h=150 meters
A
B
C
D
E
F
Diffusion Factor X/Q (sec/m3)
Distance from Release Point (meters)


ELEVATED RELEASE
ATMOSPHERIC DIFFUSION FACTORS
8–24 HOUR RELEASE TIME
h=50 meters
h=75 meters
h=100 meters
h=125 meters
h=150 meters
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
10⁻⁸
Diffusion Factor χ/Q (sec/m³)
10²
10³
10⁴
10⁵
Distance from Release Point (meters)

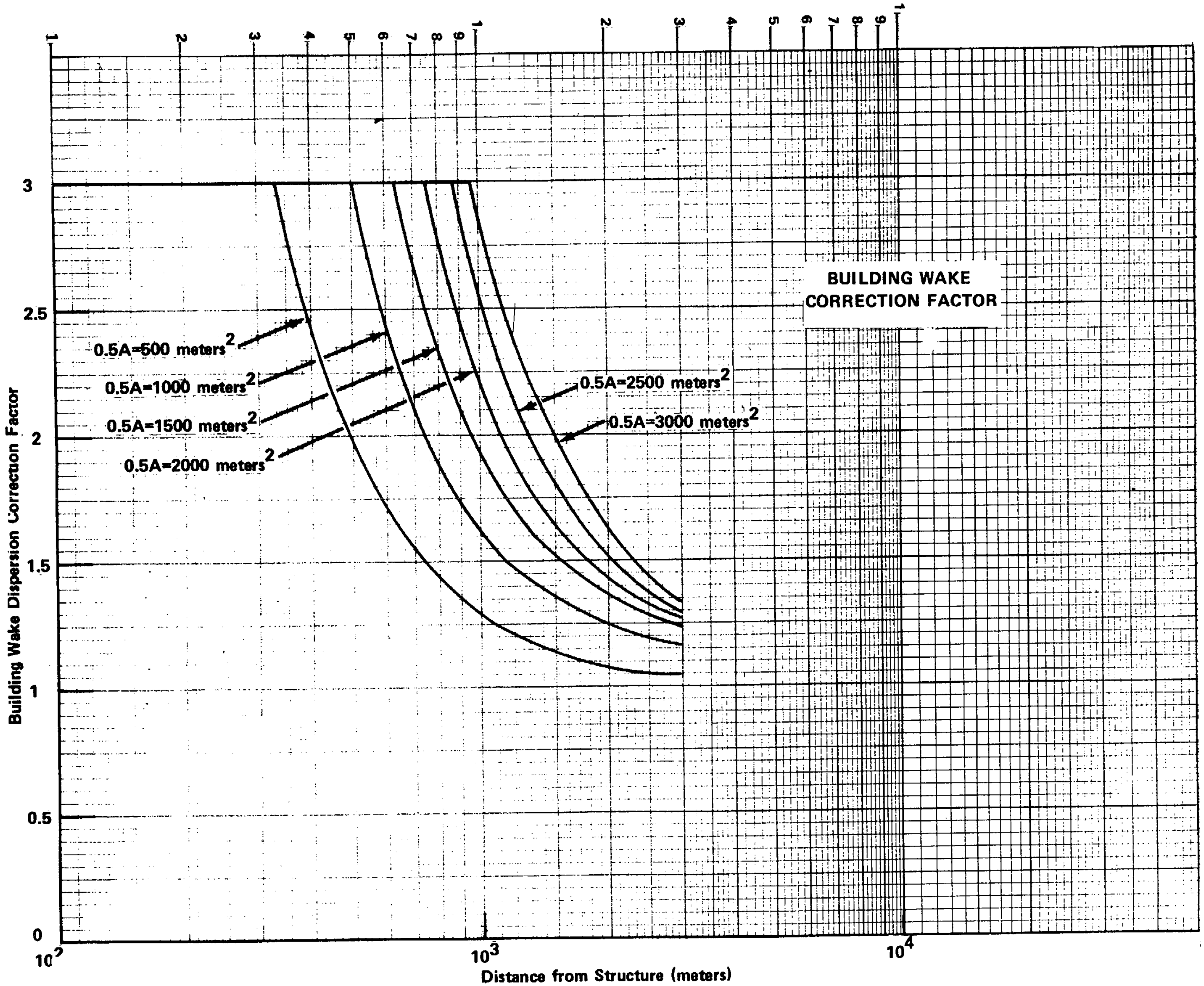

ELEVATED RELEASE
ATMOSPHERIC DIFFUSION FACTORS
1-4 DAY RELEASE TIME
FIGURE 1(C)
h = 75 meters
h = 100 meters
h = 150 meters
Diffusion Factor X/Q (sec/m³)
Distance from Release Point (meters)
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
10⁻⁸
10²
10³
10⁴
10⁵



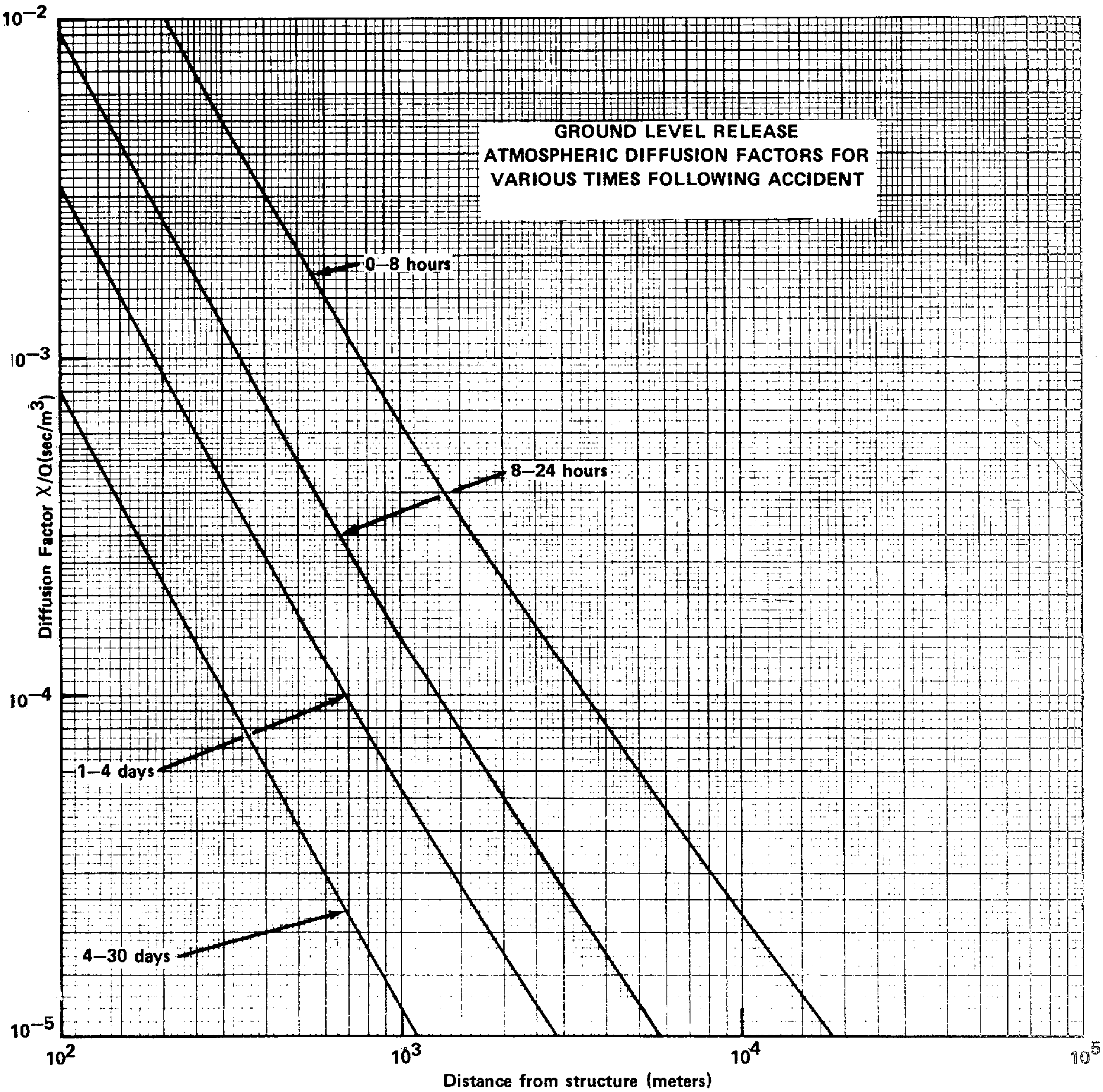
ELEVATED RELEASE
ATMOSPHERIC DIFFUSION FACTORS
4 - 30 DAYS RELEASE TIME
FIGURE 1(D)
h = 50 meters
h = 75 meters
h = 100 meters
h = 150 meters
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
Diffusion Factor X/Q (sec/m^3)
10^{2}
10^{3}
10^{4}
10^{5}
Distance from Release Point (meters)



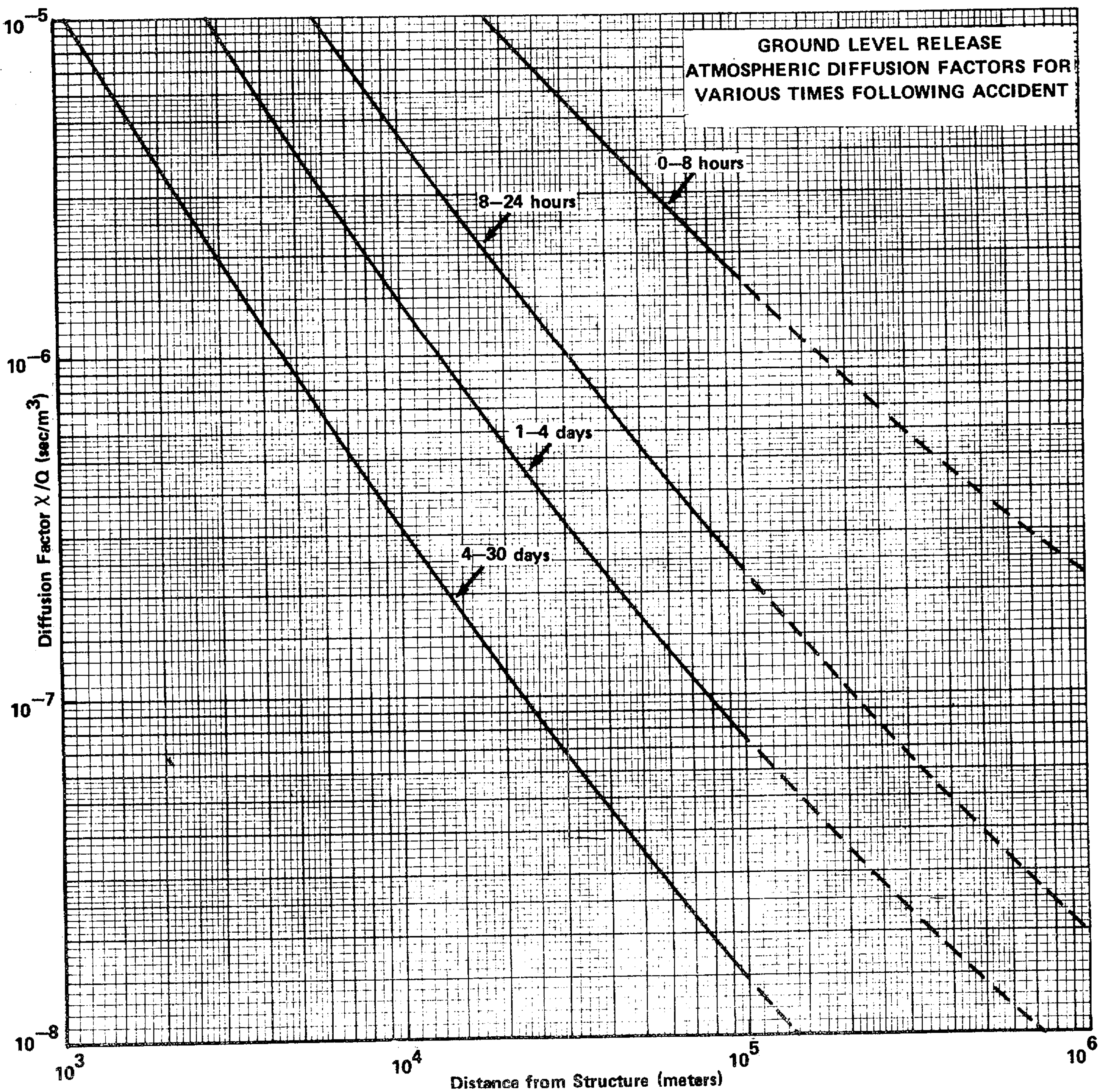
ELEVATED RELEASE
ATMOSPHERIC DISPERSION FACTORS
FOR FUMIGATION CONDITIONS
-ATMOSPHERIC CONDITIONS-
PASQUILL TYPE F
WINDSPEED 1 METER/SEC
h=50 meters
h=75 meters
h=100 meters
h=125 meters
h=150 meters
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
Diffusion Factor χ/Q (sec/m^3)
10^2
10^3
10^4
10^5
Distance from Release Point (meters)



BUILDING WAKE CORRECTION FACTOR
0.5A=500 meters^2
0.5A=1000 meters^2
0.5A=1500 meters^2
0.5A=2000 meters^2
0.5A=2500 meters^2
0.5A=3000 meters^2
Building Wake Dispersion Correction Factor
Distance from Structure (meters)
0
0.5
1
1.5
2
2.5
3
10^2
10^3
10^4



GROUND LEVEL RELEASE
ATMOSPHERIC DIFFUSION FACTORS FOR
VARIOUS TIMES FOLLOWING ACCIDENT
0–8 hours
8–24 hours
1–4 days
4–30 days
10^{-2}
10^{-3}
10^{-4}
10^{-5}
Diffusion Factor χ/Q(sec/m^3)
10^2
10^3
10^4
10^5
Distance from structure (meters)



GROUND LEVEL RELEASE
ATMOSPHERIC DIFFUSION FACTORS FOR
VARIOUS TIMES FOLLOWING ACCIDENT
0–8 hours
8–24 hours
1–4 days
4–30 days
Diffusion Factor χ/Q (sec/m³)
10⁻⁵
10⁻⁶
10⁻⁷
10⁻⁸
10³
10⁴
10⁵
10⁶
Distance from Structure (meters)