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REGULATORY GUIDE

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ASSUMPTIONS USED FOR EVALUATING THE POTENTIAL RADIOLOGICAL CONSEQUENCES OF A RADIOACTIVE OFFGAS SYSTEM FAILURE IN A BOILING WATER REACTOR

A. INTRODUCTION

Section 50.34, "Contents of Applications: Technical Information," of 10 CFR Part 50, "Licensing of Production and Utilization Facilities," 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. General Design Criterion 61, "Fuel Storage and Handling and Radioactivity Control," of Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50 requires, in part, that systems which may contain radioactivity be designed to ensure adequate safety under normal and postulated accident conditions.

Radioactive offgas systems of boiling water nuclear power reactors are used to permit decay of radioactive gases as a means of reducing the release of radioactive materials to the atmosphere. The accidental release of the contents from this system is a postulated accident used to evaluate the adequacy of these systems with respect to the public health and safety. This guide provides assumptions acceptable to the NRC staff for use in evaluating the offsite radiological consequences of this postulated accident. In some cases, unusual site characteristics, plant design features, or other factors may require different assumptions which will be considered on a case-by-case basis.

B. DISCUSSION

Offgas systems of boiling water reactors are designed to reduce the release of radioactive materials to the atmosphere. Both radioactive and nonradioactive gases are dissolved in the reactor coolant of boiling water reactors and are released to the steam in the boiling process. The radioactive gases are activation gases such as N-13, N-16, and O-19 that are formed from elements which become radioactive in passage through the reactor core from the effect of neutrons and fission gases such as the noble gases krypton and xenon that arise from the burnup of fuel. The nonradioactive gases are air that is introduced into the reactor coolant with the makeup feedwater or in leakage into the turbine condenser and hydrogen and oxygen produced by radiolytic decomposition of the coolant. The nonradioactive gases are by far the principal constituents of gases in the coolant. Gases are removed from the condensing steam in the main condenser by the steam jet air ejectors (SJAE) and then treated by the radioactive offgas system.

A series of parametric studies (Ref. 1) has been performed to assess the radiological consequences of an offgas system accident based on the dose that an individual located at the site boundary would receive from short-term release of the noble gases and their daughters, activation gases, iodine, and particulate matter on the high-efficiency particulate air (HEPA) filters. The accident postulated by the staff assumes release of 100% of the noble gas inventory stored in the system and a

fractional release of the particulate matter on the filter under upset conditions involving explosion or fire.

Although WASH-1338, in some cases, postulates total release of the material trapped on the HEPA filter located at the end of the delay line, this guide does not specify the fractional release of particulates to be used and the applicant should substantiate his selection of a specified fractional release. This fractional release will be evaluated on a case-by-case basis. When more information pertaining to the fractional release of particulate matter from HEPA filters under upset conditions is available, this guide will be revised to include a specific particulate release fraction.

C. REGULATORY POSITION

1. The assumptions related to the release of radioactive material from the fuel are:

a. A noble gas release rate at the SJAE such that it would equal 350,000 μCi/sec after 30-min delay, for a period of 30 days preceding the postulated accident and of 100,000 μCi/sec (at 30-min delay) for times earlier than 30 days for a 3500 MWt reactor. The release rate should be scaled linearly for reactors of higher and lower powers.

b. The isotopic composition of the noble gases may be determined from Table 1.

TABLE 1
NOBLE GAS SOURCE TERM

Isotope	Approx. Half-Life	Source Term, μCi/sec 0 Decay	Source Term, μCi/sec 30-Min. Decay
Xe-140	13.7 s	1.1×10^6	
Kr-90	33 s	9.8×10^5	
Xe-139	41.0 s	9.8×10^5	
Kr-89	3.2 m	4.6×10^5	6.9×10^2
Xe-137	3.8 m	5.3×10^5	2.2×10^3
Xe-138	14.0 m	3.1×10^5	7.0×10^4
Xe-135m	15.6 m	9.1×10^4	2.4×10^4
Kr-87	76 m	7.0×10^4	5.3×10^4
Kr-83m	1.86 hr	1.2×10^4	1.0×10^4
Kr-88	2.8 hr	7.0×10^4	6.2×10^4
Kr-85m	4.4 hr	1.1×10^6	1.0×10^4
Xe-135	9.2 hr	7.7×10^4	7.4×10^4
Xe-133m	2.3 d	1.0×10^3	1.0×10^3
Xe-133	5.27 d	2.9×10^4	2.9×10^4
Xe-131m	11.9 d	5.2×10^1	5.2×10^1
Kr-85	10.76 y	7.0×10^1	7.0×10^1
	Total	$\sim 4.7 \times 10^6$	$\sim 3.4 \times 10^5$

2. The assumptions related to the release of radioactive material from the processing equipment are:

a. The release from the SJAE is assumed to occur from a break in the delay line just downstream of the SJAE. The SJAE is assumed to operate for a period of 1 hour after the accident unless a positive means (automatic isolation) is provided to limit the release from this source. The release from the SJAE is assumed to be at ground level, and a delay of 5 minutes is assumed to account for transit from the SJAE to the break in the delay line.

b. Activation gases and iodine are neglected.

c. It is assumed that there is no deposition or decay during downwind transport.

d. The total radioactive content (neglecting activation gases and iodine) of the delay line is assumed to be released over a period of 2 hours.

e. The total noble gas content of the charcoal delay beds is assumed to be released over a period of 2 hours.

f. The assumed absorption coefficients for ambient temperature systems are K(Xe) = 1000 cm^3/g and K(Kr) = 65 cm^3/g and, for chilled temperature systems, are K(Xe) = 8000 cm^3/g and K(Kr) = 333 cm^3/g.

g. Condenser air inleakage is assumed to be 6 scfm.

3. The atmospheric diffusion assumptions* for ground-level releases are:

a. 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 (curies/meter^3)

Q = amount of material released (curies/sec)

u = windspeed (meters/sec)

σ_y = the horizontal standard deviation of the plume (meters) [See Figure V-1, Page 48, of Ref. 2]

*These diffusion assumptions should be used until adequate site meteorological data are obtained. In some cases, available information on such site conditions as meteorology, topography, and geographical location may dictate the use of more restrictive parameters to ensure a conservative estimate of potential offsite exposures.

σ_z = the vertical standard deviation of the plume (meters) [See Figure V-2, Page 48, of Ref. 2]

b. For ground-level releases, atmospheric diffusion factors used in evaluating the radiological consequences of the accident addressed in this guide are based on the following assumptions:

(1) windspeed of 1 meter/sec;

(2) uniform wind direction;

(3) Pasquill diffusion category F.

c. Figure 1 is a plot of atmospheric diffusion factors (χ/Q) versus distance derived by use of the equation for a ground-level release given in regulatory position 3.a. above under the meteorological conditions given in regulatory position 3.b. above.

d. Atmospheric diffusion factors for ground-level releases 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. The volumetric building wake correction as defined in Subdivision 3-3.5.2 of Reference 3 is used with a shape factor of 1/2 and the minimum cross-sectional area of the building from which the release emanates.

4. The following assumptions and equations may be used to obtain conservative approximations of external whole body dose from radioactive clouds:

a. External whole body doses are calculated using "Infinite Cloud" assumptions; i.e., the dimensions of the cloud are assumed to be large compared to the distances that the gamma rays and beta particles travel. The dose at any distance from the reactor is calculated based on the maximum ground-level concentration at that distance.

For an infinite uniform cloud containing χ curies of beta radioactivity per cubic meter, the beta dose rate in air at the cloud center is (Chapter 7 of Ref. 3):

$$_{\beta}D'_{\infty} = 0.457\, E_{\beta}\chi$$

Where

$_{\beta}D_{\infty}$ = beta dose rate from an infinite cloud (rad/sec)

$\bar{E}_{\beta}$ = average beta energy per disintegration (Mev/dis)

χ = concentration of beta or gamma emitting isotope in the cloud (curie/m^3)

Because of the limited range of beta particles in tissue, the surface body dose rate from beta emitters in the infinite cloud can be approximated as being one-half this amount or:

$$_{\beta}D'_{\infty} = 0.23\, \bar{E}_{\beta}\chi$$

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

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

Where

$_{\gamma}D'_{\infty}$ = gamma dose rate from an infinite cloud (rad/sec)

$\bar{E}_{\gamma}$ = average gamma energy per disintegration (Mev/dis)

However, because of the presence of the ground, the receptor is assumed to be exposed to only one-half of the cloud (semi-infinite) and the equation becomes:

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

Thus the total beta or gamma dose to an individual located at the center of the cloud path may be approximated as:

$$_{\beta}D_{\infty} = 0.23\, \bar{E}_{\beta}\psi$$

or

$$_{\gamma}D = 0.25\, \bar{E}_{\gamma}\psi$$

Where ψ is the concentration time integral for the cloud (curies-sec/m^3).

b. The beta and gamma energies emitted per disintegration, as given in Reference 4, are averaged and used according to the methods described in Reference 5.

D. IMPLEMENTATION

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

This guide reflects current NRC staff practice. Therefore, except in those cases in which the applicant proposes an acceptable alternative method for complying with the specified portions of the Commission's regulations, the method described herein is being and 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.

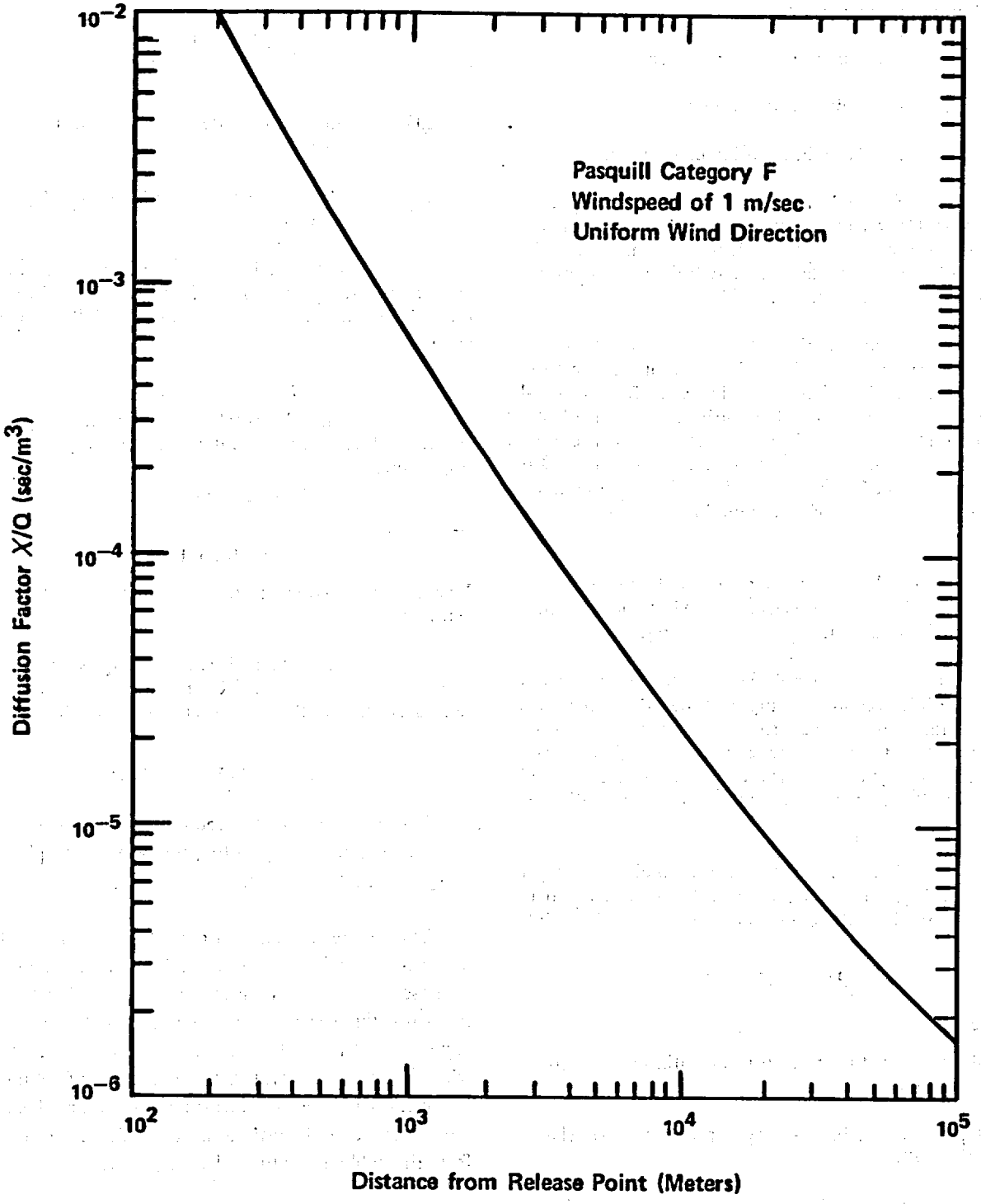

Figure 1 GROUND LEVEL RELEASE ATMOSPHERIC DIFFUSION FACTORS

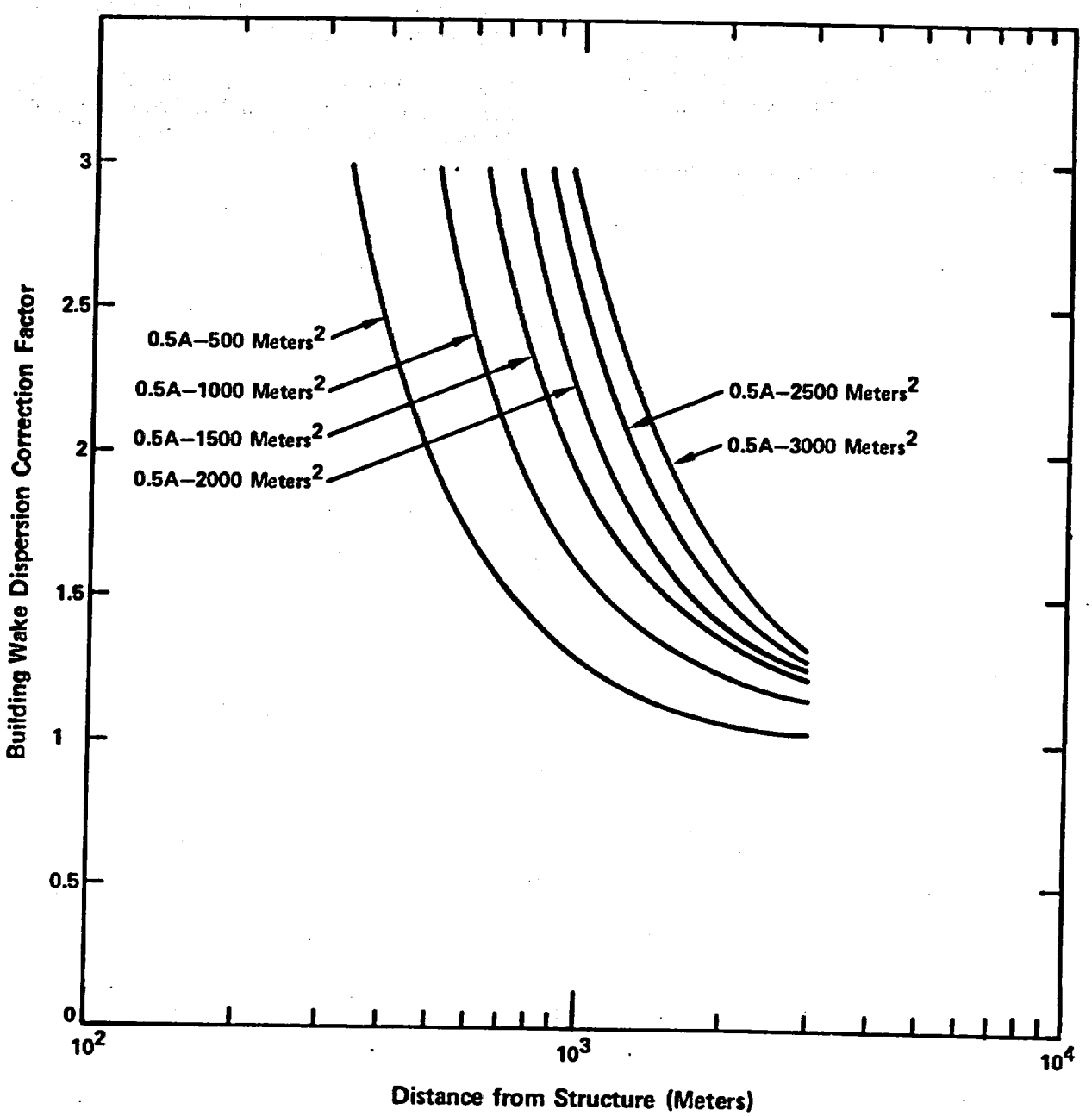

Figure 2 BUILDING WAKE CORRECTION FACTOR

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