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DRAFT REGULATORY GUIDE

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DRAFT REGULATORY GUIDE DG-1270

(Proposed Revision 2 of Regulatory Guide 1.91, dated February 1978)

EVALUATIONS OF EXPLOSIONS POSTULATED TO OCCUR AT NEARBY FACILITIES AND ON TRANSPORTATION ROUTES NEAR NUCLEAR POWER PLANTS

A. INTRODUCTION

This regulatory guide describes for applicants and licensees of nuclear power reactors methods the staff of the U.S. Nuclear Regulatory Commission (NRC) finds acceptable for evaluating postulated explosions at nearby facilities and transportation routes. It describes the calculation of minimum safe distance based on estimates of Trinitrotoluene (TNT)-equivalent mass of potentially explosive materials, the calculation of exposure rates based on potentially explosive cargo transportation frequencies, and the calculation of blast load effects.

Title 10 of the *Code of Federal Regulations* (10 CFR), Section 100.20(b) (Ref. 1) requires that the nature and proximity of hazards related to human activity (e.g., airports, dams, transportation routes, military and chemical facilities) must be evaluated to establish site parameters for use in determining whether a plant design can accommodate commonly occurring hazards, and whether the risk of other hazards is very low. In 10 CFR 52.17(a)(vii), the NRC requires that an application for an early site permit must contain the location and description of any nearby industrial, military, or transportation facilities and routes. In 10 CFR 52.79(a)(1)(iv), the NRC requires that an application for a combined license must contain the location and description of any nearby industrial, military, or transportation facilities and routes.

General Design Criterion 4, "Environmental and Dynamic Effects Design Bases," of Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities" (Ref. 2), requires that nuclear power plant structures, systems, and components important to safety be appropriately protected against dynamic effects resulting from equipment failures and from events and conditions that may occur outside the nuclear power plant. These latter events include the effects of explosion of materials that may be at nearby facilities or carried on nearby transportation routes.

This regulatory guide is being issued in draft form to involve the public in the early stages of the development of a regulatory position in this area. It has not received final staff review or approval and does not represent an official NRC final staff position. Public comments are being solicited on this draft guide (including any implementation schedule) and its associated regulatory analysis or value/impact statement. Comments should be accompanied by appropriate supporting data. Written comments may be submitted to the Rules, Announcements, and Directives Branch, Office of Administration, U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001; submitted through the NRC's interactive rulemaking Web page at http://www.nrc.gov; or faxed to (301) 492-3446. Copies of comments received may be examined at the NRC's Public Document Room, 11555 Rockville Pike, Rockville, MD. Comments will be most helpful if received by September 6, 2011.

Electronic copies of this draft regulatory guide are available through the NRC's interactive rulemaking Web page (see above); the NRC's public Web site under Draft Regulatory Guides in the Regulatory Guides document collection of the NRC's Electronic Reading Room at http://www.nrc.gov/reading-rm/doc-collections/; and the NRC's Agencywide Documents Access and Management System (ADAMS) at http://www.nrc.gov/reading-rm/adams.html, under Accession No. ML110390554. The regulatory analysis may be found in ADAMS under Accession No. ML110400261.

This guide describes methods acceptable to the NRC staff for determining whether the risk of damage due to an explosion at a nearby facility or on a transportation route is sufficiently high to warrant a detailed investigation. Acceptable methods for evaluating structural adequacy when an investigation is warranted are also described. This guide considers the effects of air blasts from explosions on highway, rail, water routes, pipelines, and nearby fixed facilities. Regulatory Guide 1.189, "Fire Protection for Nuclear Power Plants" (Ref. 3), also addresses the potential for fires and explosions both onsite and from nearby fixed facilities.

The NRC issues regulatory guides to provide the public with methods the NRC staff considers acceptable for use in implementing specific parts of the agency's regulations. These regulatory guides also describe techniques that the staff uses to evaluate specific problems or postulated accidents, and data that the staff needs to review applications for permits and licenses. Regulatory guides are not substitutes for regulations and compliance with the guides is not required. Methods and solutions that differ from those set forth in regulatory guides will be deemed acceptable if they provide a basis for the findings required for the issuance or continuance of a permit or license by the Commission.

This regulatory guide contains information collection requirements covered by 10 CFR Part 50 (Ref. 2), 10 CFR Part 52, "Licenses, Certification, and Approvals for Nuclear Power Plants" (Ref. 4), and 10 CFR Part 100, "Reactor Site Criteria" (Ref. 1) that the Office of Management and Budget (OMB) approved under OMB Control Numbers 3150-0011, 3150-0151, and 3150-0093 respectively. The NRC may neither conduct nor sponsor, and a person is not required to respond to, an information collection request or requirement unless the requesting document displays a currently valid OMB control numbers. The NRC has determined that this regulatory guide is not a major rule as designated by the Congressional Review Act and has verified this determination with OMB.

B. DISCUSSION

In order to meet General Design Criterion 4, "Environmental and Dynamic Effects Design Bases," of Appendix A to 10 CFR Part 50 with respect to dynamic effects, the structures, systems and components important to safety of a nuclear power plant must be appropriately protected against dynamic effects that may result from equipment failures and from events and conditions outside the nuclear power unit.

The effects of explosions that are of concern in analyzing structural response to blasts are incident or reflected pressure (overpressure), dynamic (drag) pressure, blast-induced ground motion, and blast generated missiles. It is the judgment of the NRC staff that, for explosions of the magnitude considered in this guide and the structures, systems, and components that must be protected, overpressure effects are controlling. Drag pressure effects will be much smaller than those resulting from the wind loading assumed for the design basis tornado. The effects of blast generated missiles will be less than those associated with the blast overpressure levels considered in this guide. However, if the overpressure criteria described in this guide is exceeded, the effects of missiles should therefore be considered. The effects of blast-induced ground motion at the overpressure levels considered in this guide will be less than those of the vibratory ground motion associated with the safe-shutdown earthquake.

This regulatory guide describes a method for determining distances from critical plant structures to a fixed facility, railway, highway, navigable waterway, or pipeline beyond which any explosion that might occur is not likely to have an adverse effect on plant operation or prevent a safe shutdown. Beyond these distances, a detailed review of potential explosions at the fixed facility or on these transportation routes would not be required.

A method for establishing the distances beyond which no adverse effect would occur can be based on a level of peak positive incident overpressure (designated as P_{so} in Department of Defense Unified Facilities Criteria (UFC) 3-340-02, "Structures to Resist the Effects of Accidental Explosions," December 5, 2008 (Ref. 5)) below which no significant damage would be expected. It is the judgment of the NRC staff that, for the structures, systems, and components of concern, this level can be conservatively chosen at 1.0 pound per square inch (psi) (approximately 6.9 kilopascals (kPa)). Based on the experimental data on hemispherical charges of TNT cited in UFC 3-340-02 (Ref. 5), the minimum safe distance from an explosion that result in P_{so} equal to 1.0 psi (6.9 KPa) can be calculated as:

$$R_{min} = Z * W^{\frac{1}{3}} \quad (1)$$

where

R_{min} = distance from explosion where P_{so} will equal 1.0 psi (6.9 KPa) (feet or meters)
W = mass of TNT (pounds or kilograms (kg))
Z = scaled distance equal to 45 ($ft/lb^{1/3}$) when R is in feet and W is in pounds
Z = scaled distance equal to 18 ($m/kg^{1/3}$) when R is in meters and W is in kilograms

A safe distance from a source of potential explosion to critical plant structures would be equal to, or greater than, R_{min}.

The concept of TNT equivalence (i.e., finding the mass of the substance in question that will produce the same blast effect as a unit of mass of TNT) has long been used in establishing safe separation distances for explosives. For substances intended to be used as explosives, TNT equivalence or relative effectiveness (R.E.) factors are reported by the manufacturers or the equivalent TNT weight, for use in

Equation (1), can be determined, based on the weight and heat of detonation of the material, using the following relationship from UFC 3-340-02 (Ref. 5).

$$W_E = \frac{H^d_{EXP}}{H^d_{TNT}} W_{EXP} \tag{2}$$

where

W_E = effective charge weight (equivalent TNT charge mass for use in Equation (1))
W_{EXP} = weight of the explosive in question
H^d_{EXP} = heat of detonation of explosive in question (values available in UFC 3-340-02 (Ref. 5))
H^d_{TNT} = heat of detonation of TNT (values available in UFC 3-340-02 (Ref. 5))

When establishing safe standoff distances for solid substances not intended for use as explosives but subject to accidental detonations, the minimum TNT equivalence (R.E. factor) used should be 1 (i.e., use the mass of potentially explosive material as the mass of TNT in Equation (1)).

The TNT equivalence concept may also be applied to detonations of either confined or unconfined vapor clouds formed as a result of the presence of potentially explosive materials. The blast energy realized depends, in great measure, on phenomena that are accident specific (i.e., the amount of vapor formation due to substances stored or released and the way in which the vapor cloud is ignited). However, investigations of accidents and experimental data have yielded basic equations for use in estimating TNT equivalence for vapor clouds. One common method for assessing the blast wave effects of vapor cloud explosions is based on the blast wave energy (i.e., TNT equivalence) given by NUREG-1805, *Fire Dynamics Tools (FDT^s) Quantitative Fire Hazard Analysis Methods for the U.S. Nuclear Regulatory Commission Fire Protection Inspection Program*, issued December 2004 (Ref. 6), and the *Society of Fire Protection Engineers' Handbook of Fire Protection Engineering* (Ref. 7):

$$E = \alpha \Delta H_c m_F \tag{3}$$

where

E = blast wave energy (British Thermal Units (BTU) or kilojoules (kJ))
α = yield (i.e., the fraction of available combustion energy participating in blast wave generation)
ΔH_c = theoretical net heat of combustion (BTU/lb_m or kJ/kg)
m_F = mass of flammable vapor released (lb_m or kg)

The corresponding TNT equivalent mass in lb_m or kg, W_{TNT} (see Ref. 7) is

$$W_{TNT} = \frac{E}{3560\ BTU/lb_m} \ or \ \frac{E}{4500\ kJ/kg} \tag{4}$$

Values for heat of combustion and yield are available in NUREG-1805 (Ref. 6) and Factory Mutual (FM) Global's "Property Loss Prevention Data Sheets 7-42" (Ref. 8). For example, the FM Data Sheets 7-42 (Ref. 8) assign explosion efficiency factors (i.e., yields) based on the class of material. A detailed analysis of possible accident scenarios for particular sites including consideration of the actual amount of potentially explosive material, potential release, site topography, and prevailing meteorological conditions should be used to justify a value for the yield. However, for establishing safe standoff distances independent of site conditions, use of a conservative estimate for the yield is prudent. To estimate the mass of flammable vapor, several methods are available, including those described in FM Data Sheets 7-42 (Ref. 8) and the methodology in Woodward's 1998 *Estimating the Flammable Mass of a Vapor Cloud* (Ref. 9).

For releases of vapor clouds at offsite locations or pipelines, plume modeling based on site topography and meteorological conditions should be evaluated. The atmospheric transport of released vapor clouds should be calculated using a dispersion or diffusion model that permits temporal as well as spatial variations in release terms. Methodology for plume modeling can be found in Chapter 5 of NUREG/CR-6410, *Nuclear Fuel Cycle Facility Accident Analysis Handbook* (Ref. 10), as appropriate.

Determining the maximum probable quantity of potentially explosive cargo on traffic routes depends on both the transportation mode and the vehicles used. The maximum probable solid cargo for a single highway truck is 50,000 pounds (23,000 kg). Similarly, the maximum probable cargo in a single railroad boxcar is approximately 132,000 pounds (60,000 kg). The largest probable quantity of material transported by ship is approximately 10,000,000 pounds (4,500,000 kg). When shipments are made in connected vehicles, such as railroad cars or barge trains, investigation of the possibility that the contents of more than one vehicle may explode is necessary.

In cases where the distances from a nearby fixed facility or transportation route to the structures, systems, and components that must be protected are not sufficiently great to allow a conclusion (based on conservative assumptions) that the peak positive incident overpressure would be less than 1.0 psi (approximately 6.9 kPa), an analysis of the probability of potential accidents at nearby facilities or the frequency of hazardous cargo shipment may show that the attendant risk is sufficiently low. It is the judgment of the NRC staff that if the probability of an explosion at a nearby facility or the exposure rate (defined in Equation (5) below based on the theory in FMEA's *Handbook of Chemical Hazard Analysis Procedures* Ref. 11) for material in transit, can be shown to be less than $1\text{x}10^{-7}$ per year, then the risk of damage due to explosions is sufficiently low.

The following equation defines the exposure rate for potentially explosive material in transit:

$$r = nfs \tag{5}$$

where

r = exposure rate
n = explosion rate for the substance and transportation mode in question, in explosions per mile or kilometer
f = frequency of shipment for the substance in question in shipments per year
s = exposure distance in miles or kilometers (see Appendix A to this guide, exposure distance calculation)

If the substance in question is shipped on more than one transportation mode near the plant, exposure rates calculated for the modes should be summed.

If an adequate database for estimating the explosion rate for a substance is lacking, an estimate can be made by using nationwide statistics for the particular transportation mode:

$$n = n_1 n_2 \tag{6}$$

where

n_1 = accidents per mile for the transportation mode
n_2 = cargo explosions per accident for the transportation mode

Because the events under consideration have a low frequency of occurrence, estimates based on average frequency may have wide confidence bands, and conservative estimates may be preferred. If estimates of explosion rate, frequency of shipment, and exposure distance are made on a realistic or best estimate basis, an exposure rate less than 1×10^{-7} per year is sufficiently low. If conservative estimates are used, an exposure rate less than 1×10^{-6} per year is sufficiently low.

If it cannot be shown that the distance to the fixed facility or transportation route is great enough or that the probability or exposure rate is low enough to render sufficiently low the risk of damage to a structure housing a system or component that must be protected, an analysis of the blast load effects may be made. The methodology from UFC 3-340-02 (Ref. 5) can be used to model the blast pressure, characterize the structure's resistance to load, and determine the response of the structure to the blast pressure. The appropriate pressure to use, reflected or incident, is dependent on the orientation of the element being analyzed and the direction of propagation of the blast wave. An acceptable result of the analysis, maximum response, will show that the structure responds in an elastic manner to the applied blast pressure loading. The blast pressure should be considered to act both inward and outward in order to account for dynamic stress reversal. Overturning and sliding stability as well as the ability of supporting structures to carry loads transmitted from the directly loaded exterior surfaces should be assessed.

The structure's resistance to load should be reduced to account for the capacity used to resist the following load combination:

$$C = D + L + T_o + R_o \tag{7}$$

where

C = combined load effect (psi or kPa)
D = dead load effect (psi or kPa)
L = live load effect (not including wind or snow loads) (psi or kPa)
T_o = thermal load effect during normal operating or shutdown conditions (psi or kPa)
R_o = pipe reaction effect during normal operating conditions (psi or kPa)

C. REGULATORY POSITION

In the design of nuclear power plants, the ability to withstand the possible effects of explosions occurring at nearby facilities and on transportation routes should be considered. The following three methods are acceptable to the NRC staff for ensuring that the risk of damage due to an explosion at nearby facilities or on a transportation route is sufficiently low.

1. The minimum safe distance can conservatively be determined by using Equation (1) based on TNT equivalent methodology. When potentially explosive materials are handled at nearby facilities no closer than the minimum safe distance computed, or carriers that transport potentially explosive materials can approach vital structures of a nuclear facility no closer than the minimum safe distance computed, no further consideration need be given to the effects of explosions from these sources in plant design. For calculating TNT equivalents, Table 1 provides acceptable assumptions for determining the mass of TNT to use in Equation (1). Lower effective yields may be justified by analyses accounting for release scenarios, reaction kinetics, site topography, and prevailing meteorological conditions when the potentially explosive materials can be identified. For unconfined vapor explosions, for which the material class is not identifiable, the staff recommends use of 15 percent yield.

Table 1 Assumption for Determining Mass of TNT

Materials	For Mass of TNT
Solids not intended for use as explosives	Use actual weight of material
Explosive materials	Use known TNT equivalent (R.E. factor) or effective charge weight determined by Equation (2)
Confined Vapors (Ref. 6)	Use α=100% in Equation (3)
Class I Unconfined Vapors (Ref. 8)	Use α=5% in Equation (3)
Class II Unconfined Vapors (Ref. 8)	Use α=10% in Equation (3)
Class III Unconfined Vapors (Ref. 8)	Use α=15% in Equation (3)
Unconfined vapors of unknown class and BLEVEs (Ref. 8)	Use α=15% in Equation (3)

2. If the facility with potentially explosive materials or the transportation routes are closer to structures, systems, and components important to safety than the distances computed using Equation (1), the applicant may show that the risk is acceptably low on the basis of low probability of explosions. A demonstration that the rate of exposure to a peak positive incident overpressure in excess of 1.0 psi (6.9 kPa) is less than $1x10^{-6}$ per year when based on conservative assumptions, or $1x10^{-7}$ per year when based on realistic assumptions, is acceptable. Due consideration should be given to the comparability of the conditions on the route to those of the accident database.

3. If the facility with potentially explosive materials or the transportation routes are closer to structures, systems, and components important to safety than the distances computed using Equation (1), the applicant may show through analysis that the risk to the public is acceptably low on the basis of the capability of the safety-related structures to withstand blast and missile effects associated with detonation of the potentially explosive material. The analysis should include the following:

a. Justification for any reduction in the TNT equivalent mass based on reaction kinetics, site topography, or prevailing meteorological conditions.
b. Characterization of the blast pressure acting on the structure, including any reflection based on orientation, using the methodology from UFC 3-340-02 (Ref. 5).
c. Characterization of the structure's resistance to load, using the methodology from UFC 3-340-02 (Ref. 5) (the resistance to load should be reduced to account for the capacity used to resist the load combination in Equation (7)).
d. Response of the structure to the blast pressure, using methodology from UFC 3-340-02 (Ref. 5), that shows the structure responds in an elastic manner (blast pressure should be considered to act both inward and outward in order to account for dynamic stress reversal).
e. Analysis of overturning and sliding stability as well as the ability of supporting structures to carry loads transmitted from the directly loaded exterior surfaces must be assessed.
f. Analysis showing the structure can resist missiles can be accomplished using the methodology from Kennedy's 1976, *A Review of Procedures for the Analysis and Design of Concrete Structures to Resist Missile Impact Effects* (Ref. 12) for concrete structures and Williamson and Alvy's 1973, *Impact Effects of Fragments Striking Structural Elements* (Ref. 13) for steel structures. Additional information on missile effects over safety-related structural barriers can be found in NUREG-0800, Chapter 3.5.3, "Barrier Design Procedures" (Ref. 14).

D. IMPLEMENTATION

The purpose of this section is to provide information on how applicants and licensees[1] may use this guide and information regarding the NRC's plans for using this regulatory guide. In addition, it describes how the NRC staff complies with the Backfit Rule (10 CFR 50.109) and any applicable finality provisions in 10 CFR Part 52.

Use by Applicants and Licensees

Applicants and licensees may voluntarily[2] use the guidance in this document to demonstrate compliance with the underlying NRC regulations. Methods or solutions that differ from those described in this regulatory guide may be deemed acceptable if they provide sufficient basis and information for the NRC staff to verify that the proposed alternative demonstrates compliance with the appropriate NRC regulations. Current licensees may continue to use guidance the NRC found acceptable for complying with the identified regulations as long as their current licensing basis remains unchanged. The acceptable guidance may be a previous version of this regulatory guide.

Licensees may use the information in this regulatory guide for actions which do not require NRC review and approval such as changes to a facility design under 10 CFR 50.59. Licensees may use the information in this regulatory guide or applicable parts to resolve regulatory or inspection issues.

Use by NRC Staff

The NRC staff does not intend or approve any imposition or backfitting of the guidance in this regulatory guide. The NRC staff does not expect any existing licensee to use or commit to using the guidance in this regulatory guide, unless the licensee makes a change to its licensing basis. The NRC staff does not expect or plan to request licensees to voluntarily adopt this regulatory guide to resolve a generic regulatory issue. The NRC staff does not expect or plan to initiate NRC regulatory action which would require the use of this regulatory guide Examples of such unplanned NRC regulatory actions include; issuance of an order requiring the use of the regulatory guide, requests for information under 10 CFR 50.54(f) as to whether a licensee intends to commit to use of this regulatory guide, generic communication, or promulgation of a rule requiring the use of this regulatory guide without further backfit consideration.

During inspections of specific facilities, the staff may recommend that licensees consider various actions consistent with staff positions in this regulatory guide, as one acceptable means of meeting the underlying NRC regulatory requirement. Such recommendations would not ordinarily be considered backfitting even if prior versions of this regulatory guide are part of the licensing basis of the facility with respect to the subject matter of the inspection. However, unless this regulatory guide is part of the licensing basis for a plant, the staff may not represent to the licensee that the licensee's failure to comply with the positions in this regulatory guide constitutes a violation.

If an existing licensee voluntarily seeks a license amendment or change and (1) the NRC staff's consideration of the request involves a regulatory issue directly relevant to this new or revised regulatory guide and (2) the specific subject matter of this regulatory guide is an essential consideration in the staff's

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[1] In this section, "licensees" refers to licensees of nuclear power plants under 10 CFR Parts 50 and 52; and the term "applicants," refers to applicants for licenses and permits for (or relating to) nuclear power plants under 10 CFR Parts 50 and 52, and applicants for standard design approvals and standard design certifications under 10 CFR Part 52.

[2] In this section, "voluntary" and "voluntarily" means that the licensee is seeking the action of its own accord, without the force of a legally binding requirement or an NRC representation of further licensing or enforcement action.

determination of the acceptability of the licensee's request, then the staff may request that the licensee either follow the guidance in this regulatory guide or provide an equivalent alternative process that demonstrates compliance with the underlying NRC regulatory requirements. This is not considered backfitting as defined in 10 CFR 50.109(a)(1) or a violation of any of the issue finality provisions in 10 CFR Part 52.

Additionally, an existing applicant may be required to adhere to new rules, orders, or guidance if 10 CFR 50.109(a)(3) applies.

Conclusion

This regulatory guide is not being imposed upon current licensees and may be voluntarily used by existing licensees. In addition, this regulatory guide is issued in conformance with all applicable internal NRC policies and procedures governing backfitting. Accordingly, the NRC's staff issuance of this regulatory guide is not considered backfitting, as defined in 10 CFR 50.109(a)(1), nor is it deemed to be in conflict with any of the issue finality provisions in 10 CFR Part 52.

If a licensee believes that the NRC is either using this regulatory guide or requesting or requiring the licensee to implement the methods or processes in this regulatory guide in a manner inconsistent with the discussion in this Implementation section, then the licensee may file a backfit appeal with the NRC in accordance with the guidance in NUREG-1409 and NRC Management Directive 8.4.

REFERENCES[3]

1. U.S. Nuclear Regulatory Commission, 10 CFR Part 100, *Reactor Site Criteria*, Washington, DC.

2. U.S. Nuclear Regulatory Commission, 10 CFR Part 50, *Domestic Licensing of Production and Utilization Facilities*, Washington, DC.

3. U.S. Nuclear Regulatory Commission, Regulatory Guide 1.189, *Fire Protection for Nuclear Power Plants*, Washington, DC, Revision 2, October 2009. (ADAMS Accession No. ML092580550)

4. U.S. Nuclear Regulatory Commission, 10 CFR Part 52, *Licenses, Certifications, and Approvals for Nuclear Power Plants*, Washington, DC.

5. Department of Defense, Unified Facilities Criteria (UFC) 3-340-02, *Structures to Resist the Effects of Accidental Explosions*, Washington, DC, December 2008 (Previous versions of this document were designated Army TM 5-1300, Air Force AFR 08-22 and Navy NAVFAC P-3897).

6. U.S. Nuclear Regulatory Commission, NUREG-1805, *Fire Dynamics Tools (FDT[s]) Quantitative Fire Hazard Analysis Methods for the U.S. Nuclear Regulatory Commission Fire Protection Inspection Program*, "Estimating the Pressure Increase and Explosive Energy Release Associated with Explosions, Chapter 15," Washington, DC, December 2004. (ADAMS Accession No. ML043290075)

7. Zalosh, Robert G., *SFPE Handbook of Fire Protection Engineering,* 2nd Edition, "Explosion Protection, Section 3, Chapter 16," Society of Fire Protection Engineers (SFPE), Boston, MA, June 1995.

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9. Woodward, John L., *Estimating the Flammable Mass of a Vapor Cloud*, Center for Chemical Process Safety, American Institute of Chemical Engineers, New York, NY, 1998.

10. U.S. Nuclear Regulatory Commission, NUREG/CR-6410, *Nuclear Fuel Cycle Facility Accident Analysis Handbook*, "Atmospheric Dispersion and Consequence Modeling, Chapter 5," Washington, DC, March 1998. (ADAMS Accession No. ML072000468)

11. Federal Emergency Management Agency, *Handbook of Chemical Hazard Analysis Procedures*, "Probability Analysis Procedures, Chapter 11," Washington, DC. November 2007.

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3 Publicly available NRC published documents are available electronically through the Electronic Reading Room on the NRC's public Web site at: http://www.nrc.gov/reading-rm/doc-collections/. The documents can also be viewed on-line or printed for a fee in the NRC's Public Document Room (PDR) at 11555 Rockville Pike, Rockville, MD; the mailing address is USNRC PDR, Washington, DC 20555; telephone 301-415-4737 or (800) 397-4209; fax (301) 415-3548; and e-mail pdr.resource@nrc.gov.

12. R.P. Kennedy, *A Review of Procedures for the Analysis and Design of Concrete Structures to Resist Missile Impact Effects*, "Nuclear Engineering and Design", Volume 37, Number 2. 183-203. 1976.

13. R.A. Williamson and R.R. Alvy, *Impact Effect of Fragments Striking Structural Elements*, Holmes and Narver, Inc. Anaheim, CA. 1973.

14. U.S. Nuclear Regulatory Commission, *NUREG-0800, Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition*, "Barrier Design Procedures, Chapter 3.5.3," Washington, DC, March 2007. (ADAMS Accession No. ML070570004).

APPENDIX A

EXPOSURE DISTANCE CALCULATION