U.S. NUCLEAR REGULATORY COMMISSION

DRAFT REGULATORY GUIDE DG-1388

Proposed Revision 3 to Regulatory Guide 1.91

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

A. INTRODUCTION

Purpose

This regulatory guide (RG) describes methods for applicants and licensees of nuclear power reactors that the U.S. Nuclear Regulatory Commission (NRC) staff finds acceptable for evaluating postulated accidental 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. This guidance also contains information on methodologies for assessing thermal effects or radiative heat flux exposure caused by explosions and fires to structures.

This guide describes methods acceptable to the NRC staff for determining if the risk of damage at the site caused by an accidental explosion at a nearby facility or on a transportation route is sufficiently high to warrant a detailed investigation to ensure safety-related systems, structures, and components (SSCs) are unaffected. 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 highways, railways, water routes, pipelines, and nearby fixed facilities.

Applicability

This guidance applies to applicants and reactor licensees subject to Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities" (Ref. 1); 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants" (Ref. 2); and 10 CFR Part 100, "Reactor Site Criteria" (Ref. 3). Though the guidance primarily reflects past reviews of large light-water nuclear power plant applications, this RG may also provide useful guidance to fuel cycle, spent fuel storage, and waste disposal facilities.

This RG is being issued in draft form to involve the public in the development of regulatory guidance in this area. It has not received final staff review or approval and does not represent an NRC final staff position. Public comments are being solicited on this DG and its associated regulatory analysis. Comments should be accompanied by appropriate supporting data. Comments may be submitted through the Federal-rulemaking Web site, http://www.regulations.gov, by searching for draft regulatory guide DG-1388. Alternatively, comments may be submitted to the Office of Administration, Mailstop: TWFN 7 A60M, U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001, ATTN: Program Management, Announcements and Editing Staff. Comments must be submitted by the date indicated in the *Federal Register* notice.

Electronic copies of this DG, previous versions of DGs, and other recently issued guides are available through the NRC's public Web site under the Regulatory Guides document collection of the NRC Library at https://nrcweb.nrc.gov/reading-rm/doc-collections/reg-guides/. The DG is also available through the NRC's Agencywide Documents Access and Management System (ADAMS) at http://www.nrc.gov/reading-rm/adams.html, under Accession No. ML21105A439. The regulatory analysis may be found in ADAMS under Accession No. ML21105A438.

Applicable Regulations

- Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50 establishes the minimum requirements for the principal design criteria for water-cooled nuclear power plants. The General Design Criteria (GDC) are also considered to be generally applicable to other types of nuclear power units and are intended to provide guidance in establishing the principal design criteria for such other units. The following GDC is of importance to evaluating postulated explosions at nearby facilities and transportation routes:

    - GDC 4, "Environmental and dynamic effects design bases," of Appendix A to 10 CFR Part 50, requires that nuclear power plant SSCs important to safety be appropriately protected against dynamic effects that may result from equipment failures and from events and conditions that may occur outside the nuclear power plant. These events include explosions of materials at nearby facilities or on nearby transportation routes.

- 10 CFR Part 100 provides requirements for proposed sites for stationary power reactors. The following requirements are specified with respect to the scope of this RG:

    - 10 CFR 100.20(b), requires that the nature and proximity of hazards related to human activity (e.g., airports, dams, transportation routes, and military and chemical facilities) be evaluated to establish site characteristics for use in determining if a plant design can accommodate commonly occurring hazards, and if the risk of other hazards is very low.

    - 10 CFR 100.21(e), requires that potential hazards associated with nearby transportation routes, industrial, and military facilities must be evaluated and site characteristics established such that the potential hazards from such routes and facilities will pose no undue risk to the type of facility proposed at the site.

- 10 CFR Part 50 provides regulations for licensing production and utilization facilities and requires applicants and licensees to assess site features that may affect the facility design. The following requirements are specified with respect to the scope of this RG:

    - 10 CFR 50.34(a)(1)(i), requires that an application for a construction permit include a description and safety assessment of the site on which the facility is to be located, with appropriate attention to features affecting facility design and special attention given to the site evaluation factors identified in 10 CFR Part 100. The guidance in this RG is intended to assist the licensee or applicant by describing methods that the NRC finds acceptable for meeting the requirements of 10 CFR Part 100.20(b).

    - 10 CFR 50.34(a)(3)(i), requires that an applicant for a water-cooled nuclear power plant establish the minimum principle design criteria as specified in the GDC in Appendix A of 10 CFR Part 50. The guidance in this RG is intended to assist the licensee or applicant by describing methods that the NRC finds acceptable for meeting the requirements of GDC 4.

- 10 CFR Part 52 governs the issuance of early site permits, standard design certifications, combined licenses, standard design approvals, and manufacturing licenses for nuclear power facilities. The guidance in this RG is intended for applicants of early site permits and combined licenses under 10 CFR Part 52. The following requirements are specified with respect to the scope of this RG:

- 10 CFR 52.17(a)(1)(vii), requires that an application for an early site permit contain the location and description of any nearby industrial, military, or transportation facilities and routes.

- 10 CFR 52.79(a)(1)(iv), requires that an application for a combined license contain the location and description of any nearby industrial, military, or transportation facilities and routes.

- 10 CFR 52.79 (a)(4)(i), requires that an application for a combined license address the GDC in Appendix A of 10 CFR Part 50. The guidance in this RG is intended to assist the licensee or applicant by describing methods that the NRC finds acceptable for meeting the requirements of GDC 4.

Related Guidance

- RG 1.189 "Fire Protection for Nuclear Power Plants" (Ref. 4), describes comprehensive guidance on fire protection program for licensees and applicants that is acceptable to the NRC staff for meeting the fire protection regulations in 10 CFR 50.48 and addresses the potential for fires and explosions both onsite and from nearby fixed facilities.

Purpose of Regulatory Guides

The NRC issues Regulatory Guides (RGs) to describe methods that are acceptable to the staff for implementing specific parts of the agency's regulations, to explain techniques that the staff uses in evaluating specific issues or postulated events, and to describe information that the staff needs in its review of applications for permits and licenses. RGs are not NRC regulations and compliance with them is not required. Methods and solutions that differ from those set forth in RGs are acceptable if supported by a basis for the issuance or continuance of a permit or license by the Commission.

Paperwork Reduction Act

This RG provides voluntary guidance for implementing the mandatory information collections in 10 CFR Parts 50, 52 and 100 that are subject to the Paperwork Reduction Act of 1995 (44 U.S.C. 3501 et. seq.). These information collections were approved by the Office of Management and Budget (OMB), under control numbers 3150-0011, 3150-0151 and 3150-0093, respectively. Send comments regarding this information collection to the Freedom of Information Act (FOIA), Library, and Information Collections Branch ((T6-A10M), U.S. Nuclear Regulatory Commission, Washington, DC 20555 0001, or by e-mail to Infocollects.Resource@nrc.gov, and to the Desk Officer, Office of Information and Regulatory Affairs, NEOB-10202 (3150-0011, 3150-0151 and 3150-0093) Office of Management and Budget, Washington, DC, 20503.

Public Protection Notification

The NRC may not conduct or sponsor, and a person is not required to respond to, a collection of information unless the document requesting or requiring the collection displays a currently valid OMB control number.

B. DISCUSSION

Reason for Revision

RG 1.91 "Evaluations of Explosions Postulated to Occur on Transportation Routes near Nuclear Power Plants," Revision 2, was issued in April 2013. The NRC issued an expert evaluation team report, "Report of the U.S. Nuclear Regulatory Commission Expert Evaluation Team on Concerns Pertaining to Gas Transmission Lines Near the Indian Point Nuclear Power Plant," (Ref.5) in April 2020 which identified several recommendations with respect to updates to RG 1.91, Revision 2. In response, this revised guide addresses those recommendations without endorsing any particular methodology or set of assumptions. It includes references to pertinent information and methodologies as available. The applicant or licensee, at their discretion, can use other methodologies and assumptions in meeting the NRC regulations and acceptance criteria. This revised guide, therefore, reflects updates based on the recommendations of the expert evaluation team report and presents information pertinent to addressing current NRC methodologies, as appropriate.

Background

To meet GDC 4 of Appendix A to 10 CFR Part 50 regarding dynamic effects, the SSCs important to safety of a nuclear power plant must be appropriately protected against dynamic effects that may result from equipment failures and 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, blast-generated missiles, and thermal effects. It is the judgment of the NRC staff that overpressure effects are controlling for explosions of the magnitude considered in this guide and for the SSCs that must be protected against these effects. 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 would be less than those associated with the blast overpressure levels considered in this guide. However, if the overpressure criterion described in this guide is exceeded, the effects of missiles should be considered. The effects of blast-induced ground motion at the overpressure levels considered in this guide should be less than those of the vibratory ground motion associated with a safe-shutdown earthquake. The effects of thermal exposure (radiative heat flux) is expected to be insignificant for concrete and steel structures but may be of concern for exposed plastic components.

This RG describes four methods for determining distances from critical plant structures to a fixed facility or transportation route beyond which any explosion or fire 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 or fire at the fixed facility or on these transportation routes would not be required.

An acceptable method for establishing the distances beyond which no adverse effect would occur is 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. 6)) below which no significant damage would be expected. The NRC staff determined that, for the SSCs of concern, this level is conservatively 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, the minimum safe distance from an explosion that results in P_{so} equal to 1.0 psi (6.9 kPa) can be calculated as:

$$R_{min} = Z * W^{\frac{1}{3}} \tag{1}$$

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. Manufacturers of substances intended to be used as explosives report the TNT equivalence (yield factor) of these substances. For use in Equation (1), the equivalent TNT weight can be determined based on the weight and heat of detonation of the explosive material using the following equation from UFC 3-340-02:

$$W_E = \frac{H_{EXP}^d}{H_{TNT}^d} W_{EXP} \tag{2}$$

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 Table 2-1 of UFC 3-340-02)
$H^d{}_{TNT}$ = heat of detonation of TNT (values available in Table 2-1 of UFC 3-340-02)

When establishing safe standoff distances for solid substances not intended for use as explosives but subject to accidental detonations, the minimum yield 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 also may 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 (e.g., the amount of vapor formation because of 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. 7), and the Society of Fire Protection Engineers' (SFPE's) "Handbook of Fire Protection Engineering" (Ref. 8):

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

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. 8) is

$$W_{TNT} = \frac{E}{1900\ BTU/lb_m}\ or\ \frac{E}{4500\ kJ/kg} \tag{4}$$

Values for heat of combustion and yield are available in NUREG-1805 and Factory Mutual (FM) Global's Property Loss Prevention Data Sheets 7–42, "Guidelines for Evaluating the Effects of Vapor Cloud Explosions Using a TNT Equivalency Method," May 2008 (Ref. 9). For example, the FM Data Sheet 7–42 assigns 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, the 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 Sheet 7–42 and the methodology in "Estimating the Flammable Mass of a Vapor Cloud" by J.L. Woodward, 1998 (Ref. 10).

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 for plume modeling. Information can be found in Chapter 5 of NUREG/CR-6410, "Nuclear Fuel Cycle Facility Accident Analysis Handbook," issued March 1998 (Ref. 11).

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 quantities for a highway truck, railroad boxcar, and ship are as follows: ax

- 50,000 lb. (22,700 kg) payload on a highway truck: This is a conservative value based on maximum allowable truck axle loads on highways (20,000 lb. (9,080 kg) on a single axle and 34,000 lb. (15,440 kg) on a tandem axle, as per 23 CFR, "Federal Highway Administration, Department of Transportation," Part 658.17 (Ref. 12)).

- 132,000 lb. (60,000 kg) payload on a railroad boxcar: This is conservative based on a nominal boxcar capacity with mandated bracings of explosive cargo and loading procedures (49 CFR, "Transportation," Part 174.101 (Ref. 13) and, 49 CFR 174.104 and Bureau of Explosives Pamphlets 6 and 6A). Department of the Air Force (AFMAN 91-201 Explosive Safety Standards) also support this maximum value.

- 10,000,000 lb. (4,500,000 kg) on a ship: This is conservative based on a typical capacity of river barges.

When shipments are made in connected vehicles, such as railroad cars or barge trains, investigating the possibility that the contents of more than one vehicle may explode is necessary.

In some cases, the distances from a nearby fixed facility or transportation route to the SSCs that must be protected may not be great enough 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). In such cases, 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. The NRC staff determined that if the frequency of an explosion at a nearby facility (fixed facility), or the exposure rate[1] associated with a transportation route for material in transit, can be shown to be less than 1×10^{-7} per year, then the risk of damage caused by 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, from UFC 3-340-02, Figure 2-7)

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 or kilometer 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 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, depends on the orientation of the element being analyzed and the direction of propagation of the blast wave. To be considered an acceptable result, the maximum response of the analysis must 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 to

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1 The exposure rate is based on the theory outlined in the Federal Emergency Management Agency's "Handbook of Chemical Hazard Analysis Procedures", November 2007 (Ref. 14).

account for dynamic stress reversal. Overturning and sliding stability should be assessed, as well as the ability of supporting structures to carry loads transmitted from the directly loaded exterior surfaces. 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)

Consideration of International Standards

The International Atomic Energy Agency (IAEA) works with member states and other partners to promote the safe, secure, and peaceful use of nuclear technologies. The IAEA develops Safety Standards and Safety Guides for protecting people and the environment from harmful effects of ionizing radiation. Through a system of safety fundamentals, safety requirements, safety guides, and other relevant reports, the IAEA presents an international perspective on what constitutes a high level of safety. To inform the development of this RG, the NRC considered IAEA Safety Requirements and Safety Guides[2] pursuant to the Commission's International Policy Statement (Ref. 15) and Management Directive and Handbook 6.6 (Ref. 16). Specifically, the NRC staff considered the following IAEA Safety Guide in the development of this RG:

- IAEA Safety Guide No. NS-G-3.1, "External Human Induced Events in Site Evaluation for Nuclear Power Plants," 2002 (Ref. 17), which identifies, describes, and evaluates the hazards of explosions at or near nuclear power plants.

Documents Discussed in Staff Regulatory Guidance

This RG endorses the use of one or more codes developed by external organizations, and other third-party guidance documents. This code may contain references to other codes, standards or third-party guidance documents ("secondary references"). If a secondary reference has itself been incorporated by reference into NRC regulations as a requirement, then licensees and applicants must comply with that standard as set forth in the regulation. If the secondary reference has been endorsed in a RG as an acceptable approach for meeting an NRC requirement, then the standard constitutes a method acceptable to the NRC staff for meeting that regulatory requirement as described in the specific RG. If the secondary reference has neither been incorporated by reference into NRC regulations nor endorsed in a RG, then the secondary reference is neither a legally-binding requirement nor a "generic" NRC approved acceptable approach for meeting an NRC requirement. However, licensees and applicants may consider and use the information in the secondary reference, if appropriately justified, consistent with current regulatory practice, and consistent with applicable NRC requirements.

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2 IAEA Safety Requirements and Guides may be found at www.IAEA.org/ or by writing the International Atomic Energy Agency, P.O. Box 100 Wagramer Strasse 5, A-1400 Vienna, Austria; telephone (+431) 2600-0; fax (+431) 2600-7; or e-mail Official.Mail@IAEA.Org. It should be noted that some of the international recommendations do not correspond to the requirements specified in the NRC's regulations, and the NRC's requirements take precedence over the international guidance.

C. STAFF REGULATORY GUIDANCE

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. Staff positions 1, 2 and 3 identify methods that are acceptable to the NRC staff for ensuring that the risk of damage caused by an explosion at nearby facilities or on a transportation route is sufficiently low. Staff position 4, discusses guidance regarding the thermal effects on structures.

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, 15 percent yield is an acceptable conservative value, based on the information presented in Ref. 8.

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 (yield factor) or effective charge weight determined by Equation (2)
Confined Vapors (Ref. 7)	Use α=100% in Equation (3)
Class I Unconfined Vapors (Ref. 9)	Use α=5% in Equation (3)
Class II Unconfined Vapors (Ref. 9)	Use α=10% in Equation (3)
Class III Unconfined Vapors (Ref. 9)	Use α=15% in Equation (3)
Unconfined vapors of unknown class and Boiling Liquid Expanding Vapor Explosions (BLEVEs) (Ref. 9)	Use α=15% in Equation (3)

2. If the facility with potentially explosive materials or the transportation routes are closer to SSCs important to safety than the distances computed using Equation (1), the applicant or licensee 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 SSCs 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 safety-related structures capability 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.

c. Characterization of the structure's resistance to load using the methodology from UFC 3-340-02 (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, which shows the structure responds in an elastic manner. Blast pressure should be considered to act both inward and outward to account for dynamic stress reversal.

e. Analysis of overturning and sliding stability must be assessed, as well as the ability of supporting structures to carry loads transmitted from the directly loaded exterior surfaces.

f. Analysis showing that the structure can resist missiles can be accomplished using the methodology from "A Review of Procedures for the Analysis and Design of Concrete Structures to Resist Missile Impact Effects," by R.P Kennedy, 1976 (Ref. 18), for concrete structures, and "Impact Effect of Fragments Striking Structural Elements," by R.A. Williamson and R.. Alvy, 1973 (Ref. 19), for steel structures. Additional information on missile effects over safety-related structural barriers can be found in NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition," Chapter 3.5.3, "Barrier Design Procedures" (Ref. 20).

4. Regarding guidance on the thermal effects or radiative heat flux exposure on power plant structures, the information in NUREG/CR-3330 (Ref. 21), 49 CFR Part 192.903 (Ref. 22), and American Society of Mechanical Engineers (ASME) B31.8S (Ref. 23) is acceptable for determining the potential impact of radiative heat flux on power plant structures exposed to explosions and fires. Baker 2005 (Ref. 24), provides information for hazardous materials other than natural gas. If the calculated radiative heat flux is found to be acceptable, no further consideration need be given to the effects of explosions or fires from these sources in facility design.

D. IMPLEMENTATION

The NRC staff may use this RG as a reference in its regulatory processes, such as licensing, inspection, or enforcement. However, the NRC staff does not intend to use the guidance in this RG to support NRC staff actions in a manner that would constitute backfitting as that term is defined in 10 CFR 50.109, “Backfitting,” and as described in NRC Management Directive 8.4, “Management of Backfitting, Forward Fitting, Issue Finality, and Information Requests,” (Ref. 25) nor does the NRC staff intend to use the guidance to affect the issue finality of an approval under 10 CFR Part 52, “Licenses, Certifications, and Approvals for Nuclear Power Plants.” The staff also does not intend to use the guidance to support NRC staff actions in a manner that constitutes forward fitting as that term is defined and described in Management Directive 8.4. If a licensee believes that the NRC is using this RG in a manner inconsistent with the discussion in this Implementation section, then the licensee may file a backfitting or forward fitting appeal with the NRC in accordance with the process in Management Directive 8.4

REFERENCES[3]

1. *U.S. Code of Federal Regulations* (CFR), "Domestic Licensing of Production and Utilization Facilities," Part 50, Chapter 1, Title 10, "Energy."

2. CFR, "Licenses, Certifications, and Approvals for Nuclear Power Plants," Part 52, Chapter 1, Title 10, "Energy."

3. CFR, "Reactor Site Criteria," Part 100, Chapter 1, Title 10, "Energy."

4. U.S. Nuclear Regulatory Commission (NRC), Regulatory Guide (RG) 1.189, "Fire Protection for Nuclear Power Plants,", Washington, DC.

5. NRC, "Report of the U.S. Nuclear Regulatory Commission Expert Evaluation Team on Concerns Pertaining to Gas Transmission Lines Near the Indian Point Nuclear Power Plant." Washington, DC, April 8, 2020. (ADAMS Accession No. ML20100F635).

6. 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-397).[4]

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

8. Zalosh, R.G., "SFPE Handbook of Fire Protection Engineering", 2nd Edition, Section 3, Chapter 16, "Explosion Protection," Society of Fire Protection Engineers (SFPE), Boston, MA, June 1995.[5]

9. Factory Mutual Global, Property Loss Prevention Data Sheets, 7–42, "Guidelines for Evaluating the Effect of Vapor Cloud Explosions Using a TNT Equivalency Method," Factory Mutual Insurance Company, Johnston, RI, May 2008.[6]

10. Woodward, J.L., "Estimating the Flammable Mass of a Vapor Cloud", Center for Chemical Process Safety, American Institute of Chemical Engineers, New York, NY, 1998.[7]

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3 Publicly available documents from the U.S. Nuclear Regulatory Commission (NRC) are available electronically through the NRC Library on the NRC's public Web site at http://www.nrc.gov/reading-rm/doc-collections/.The documents can also be viewed on-line for free 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.

4 Documents from the U.S. Army Corps of Engineers (USACE) are available from their library Web site (http://www.usace.army.mil/Library/Pages/default.aspx) ; or by contacting the headquarters at Headquarters, US Army Corps of Engineers, 441 G Street, NW, Washington, DC 20314; telephone (202) 761-001; and e-mail HQ-PublicAffairs@USACE.army.mil.

5 Documents from the Society of Fire Protection Engineers (SFPE) may be purchased from SFPE online store Website: https://netforum.avectra.com/eWeb/Shopping/Shopping.aspx?Site=SFPE&WebCode=Shopping

6 Copies of Report be obtained from FM GLOBAL GROUP, 270 Central Avenue, Johnston, Rhode Island, United States 02919, P.O. Box 7500, Johnston, Rhode Island, United States 02919 Web: www.fmglobal.com

7 Copy of Center for Chemical Process Safety, American Institute of Chemical Engineers may be obtained through Website:

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

12. CFR, "Federal Highway Administration, Department of Transportation," Chapter I, Title 23, "Highways," Subpart G, "Engineering and Traffic Operations."

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9 Copies of International Atomic Energy Agency (IAEA) documents may be obtained through its Web site: www.IAEA.Org/ or by writing the International Atomic Energy Agency P.O. Box 100 Wagramer Strasse 5, A-1400 Vienna, Austria. Telephone (+431) 2600-0, Fax (+431) 2600-7, or E-Mail at Official.Mail@IAEA.Org.

10 Copies of this paper may be purchased through Science Direct Website: http://www.sciencedirect.com

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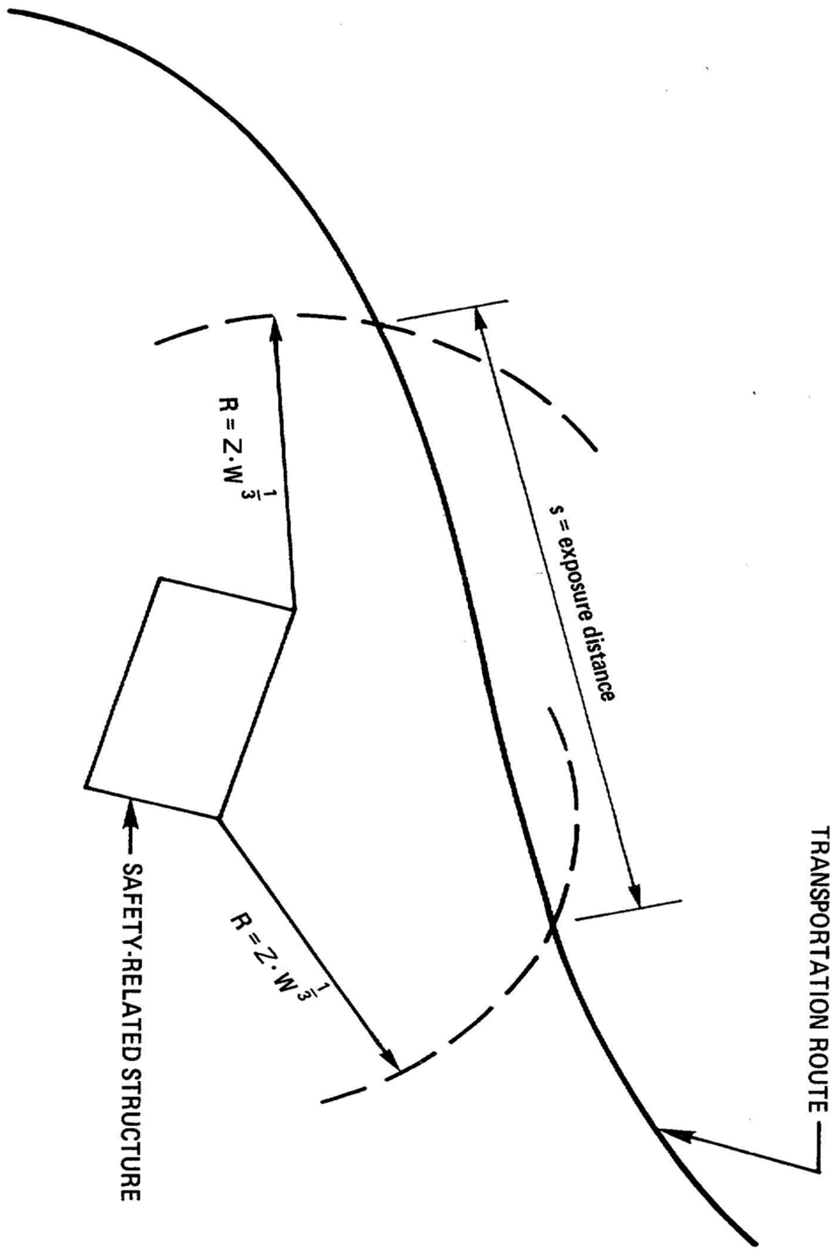
APPENDIX A

EXPOSURE DISTANCE CALCULATION



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