U.S. NUCLEAR REGULATORY COMMISSION

REGULATORY GUIDE 1.78, REVISION 2

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Technical Lead: Casper Sun

EVALUATING THE HABITABILITY OF A NUCLEAR POWER PLANT CONTROL ROOM DURING A POSTULATED HAZARDOUS CHEMICAL RELEASE

A. INTRODUCTION

Purpose

This regulatory guide (RG) describes approaches and technical bases that are acceptable to the staff of the U.S. Nuclear Regulatory Commission (NRC) to meet regulatory requirements for evaluating the habitability of a nuclear power plant (NPP) control room (CR) during a postulated hazardous chemical release. Releases of hazardous chemicals,[1] on site and off site, can result in the nearby CR becoming uninhabitable. The driver of this RG is Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities," Appendix A, "General Design Criteria for Nuclear Power Plants," General Design Criterion (GDC) 19, "Control Room," (Ref. 1). GDC 19 requires operating reactor licensees to provide a CR from which actions can be taken to maintain the nuclear power unit in a safe condition under accident conditions, including loss-of-coolant accidents.

This RG contains technical bases and guidelines that are acceptable to the NRC staff for use in assessing the habitability of a CR during and after a postulated external release of hazardous chemicals (e.g., vapor and gaseous) from a stationary source on site and multiple mobile sources off site, based on the immediately dangerous to life or health (IDLH) values (Ref. 2).

Applicability

This guidance applies to applicants and reactor licensees under 10 CFR Part 50 and 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants" (Ref. 3). Although this RG is meant for NPP applications, the technical basis and analytical methods described for chemical

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[1] As defined by the Occupational Safety and Health Administration's (OSHA's) Hazard Communication Standard, https://www.osha.gov/hazcom, a hazardous chemical is any chemical that can cause a physical or health hazard.

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Electronic copies of this RG, previous versions of RGs, and other recently issued guides are also available through the NRC's public Web site in the NRC Library at https://nrcweb.nrc.gov/reading-rm/doc-collections/reg-guides/, under Document Collections, in Regulatory Guides. This RG is also available through the NRC's Agencywide Documents Access and Management System (ADAMS) at http://www.nrc.gov/reading-rm/adams.html, under ADAMS Accession Number (No.) ML21253A071. The regulatory analysis may be found in ADAMS under Accession No. ML21119A159. The associated draft guide DG-1387 may be found in ADAMS under Accession No. ML21119A157, and the staff responses to the public comments on DG-1387 may be found under ADAMS Accession No ML21253A074.

safety could also be implemented for nonreactor and advanced non-light-water reactor facilities to address habitability concerns involving use or storage of hazardous or toxic chemicals.

Applicable Regulations

- The GDC in Appendix A to 10 CFR Part 50 establish minimum requirements for the principal design criteria for water-cooled nuclear power plants.
    - GDC 19 requires that a CR be provided from which actions can be taken to operate the nuclear power unit safely under normal conditions and to maintain it in a safe condition under accident conditions.
    - GDC 4, “Environmental and Dynamic Effects Design Bases,” requires, in part, that, like the CR, structures, systems, and components important to safety be designed to accommodate the effects of and to be compatible with normal operation, maintenance, testing, and postulated accidents.
- 10 CFR Part 50 provides regulations for licensing production and utilization facilities.
    - 10 CFR 50.34(3)(i) requires that an applicant for a water-cooled nuclear power plant establish the minimum principal design criteria as specified in the GDC in Appendix A of 10 CFR Part 50.
- 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 standard design certifications and combined license applicants under 10 CFR Part 52.
    - Section 52.47(a)(3)(i) requires an applicant for a design certification to include the facility’s principal design criteria, the minimum requirements for which are in Appendix A of 10 CFR Part 50.
    - Section 52.79(a)(4)(i) requires an applicant for a combined license to include the facility’s principal design criteria, the minimum requirements for which are in Appendix A of 10 CFR Part 50.
- 10 CFR Part 20, “Standards for Protection against Radiation,” Subpart H, “Respiratory Protection and Controls to Restrict Internal Exposure in Restricted Areas” (Ref. 4) establishes requirements to mitigate the intake of chemicals and radionuclides during routine or emergency operations. For example, Part 20, Subpart H and Appendix A contain safety requirements that are applicable to applicants and licensees in the evaluation of controlled chemical release to the CR.

Related Guidance

- RG 1.91, “Evaluations of Explosions Postulated To Occur on Transportation Routes Near Nuclear Power Plants,” (Ref. 5), describes methods for determining the risk of damage caused by an explosion (including from liquids, cryogenically liquefied hydrocarbons, vapor clouds, etc.) at a nearby facility or on a transportation route.

- RG 1.174, “An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis,” (Ref. 6), describes an approach and guidance on analyzing the risk from proposed changes in plant design and operation.

- RG 1.189, “Fire Protection for Nuclear Power Plants,” (Ref. 7), describes an approach and the associated requirements to manage a NPP’s fire protection program.

- RG 1.200, “An Approach for Determining the Technical Adequacy of Probabilistic Risk Assessment Results for Risk-Informed Activities,” (Ref. 8), describes an approach acceptable for determining whether a base probabilistic risk assessment (PRA), in total or in the portions that are used to support an application, is sufficient to provide confidence in the results. such that the PRA can be used in regulatory decision making for light-water reactors.

Purpose of Regulatory Guides

The NRC issues 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 will assist the staff with its review of applications for permits and licenses. Regulatory guides are not NRC regulations and compliance with them is not mandatory. 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 20, 50 and 52 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 3150-0014, 3150-0011 and 3150-0151, respectively. Send comments regarding this information collection to the 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 (3150-0014, 3150-0011 and 3150-0151) 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

The revision of this guide (Revision 2) presents up-to-date and defense-in-depth guidance using the latest scientific methods and the updated, NRC-endorsed computer code for CR habitability evaluation called HABIT. HABIT is an integrated set of computer codes that the NRC uses to evaluate CR habitability and estimate the control room personnel's exposure to a chemical release. Revision 1 of RG 1.78 endorsed an earlier version of HABIT, which is described in NUREG/CR-6210, Supplement 1, "Computer Codes for Evaluation of Control Room Habitability (HABIT V1.1)," issued October 1998 (Ref. 9). More recently, the NRC staff endorsed a newer version of HABIT in NUREG-2244, "HABIT 2.2: Description of Models and Methods," issued May 2021 (Ref. 10). This latest version of HABIT is available at the Radiation Protection Computer Code Analysis and Maintenance Program Web site, https://ramp.nrc-gateway.gov/.

Background

GDC 19 requires operating reactor licensees to provide a CR from which actions can be taken to maintain the nuclear power unit in a safe condition under accident conditions including protecting the CR from hazardous chemicals that may be discharged as a result of equipment failures, human errors, or events and conditions outside the control of the NPP. Based on NUREG/CR-6624, "Recommendations for Revision of Regulatory Guide 1.78," (Ref. 11), the NRC issued RG 1.78, Revision 1 in 2001. It updated the two guidance tables (i.e., Table C-1 and Table C-2) with the latest IDLH values and established the connection of CR habitability and hazardous chemicals from mobile (e.g., tank trucks, railroad cars, and barges) and stationary (e.g., storage tanks, pipelines, fire-fighting equipment) sources which in turn provided the segue for further validating the criteria and for developing the procedures used in CR habitability evaluations.

Further, NUREG/CR-6624 also affirmed that all nuclear reactor CR operators should be trained and expected to don personal protection equipment (PPE) such as respirators and protective clothing within 2 minutes, so that they will not be subjected to risk from prolonged exposure more than two minutes at the chemical's IDLH value. Table 1, "Selected IDLH Values for Twenty-Nine Hazardous Chemicals," has the same IDLH values from Revision 1 of RG 1.78.

Promulgated by OSHA, the IDLH concept was established originally for use in assigning respiratory and face-mask equipment as part of the Standards Completion Program, a joint project with the National Institute for Occupational Safety Health (NIOSH) during the mid-1970s. The IDLH values define the levels of chemical concentration that are likely to cause death or immediate or delayed permanent adverse health effects if no PPE is afforded within 30 minutes. The IDLH values are used to: (1) ensure that the worker can identify and escape from a given contaminated environment in the event of failure of the respiratory protection equipment; and (2) determine the required minimum air-purifying factor (APF) for a PPE to provide sufficient protection consistent with the criterion of Appendix A, "Assigned Protection Factors for Respirators," to 10 CFR Part 20.

Further, Table 2, "Minimum Chemical Weights That Require Consideration in CR Habitability Evaluation," of this RG illustrates the importance of distance between the release source and the CR to determine the mass (i.e., weight) of chemicals, regardless of what kind of toxic chemicals are identified. The frequency of shipments from a mobile source, the quantity and duration of a release, the toxicity of released chemicals, meteorological conditions (for dispersion calculations), and the rate of air infiltration into the CR are also documented from NUREG/CR-6624. Further, RG 1.78, Revision 1, covered both toxic and asphyxiating chemicals and recognized that the asphyxiating chemicals should only be considered in CR habitability determinations if their release could result in displacement of a significant fraction of the CR air and result in an oxygen-deficient atmosphere.

Consistent with risk-informed regulatory decision making, this RG revision encourages licensees to make greater use of risk insights in submitting applications for plant-specific changes to the licensing basis, using the guidance provided in RG 1.174. Further, this RG revision continues to provide flexibility for licensees to use traditional engineering approaches. Also, consistent with the intent of SECY-00-0191, "High-Level Guidelines for Performance-Based Activities," dated September 1, 2000 (Ref. 12), on performance-based initiatives, this RG revision provides performance-based guidance rather than traditional, prescriptive guidance.

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 Requirements and Safety Guides for protecting people and the environment from harmful effects of ionizing radiation. This system of safety fundamentals, safety requirements, safety guides, and other relevant reports, reflects an international perspective on what constitutes a high level of safety. To inform its development of this RG, the NRC considered IAEA Safety Requirements and Safety Guides pursuant to the Commission's International Policy Statement (Ref. 13) and Management Directive and Handbook 6.6, "Regulatory Guides" (Ref. 14).

The following IAEA Specific Safety Guide (SSG) documents were considered in the development/update of this RG:

- IAEA SSG-3, "Development and Application of Level 1 Probabilistic Safety Assessment for Nuclear Power Plants," issued 2010 (Ref. 15)

- IAEA SSG-54, "Accident Management Programmes for Nuclear Power Plants," issued 2019 (Ref. 16)

In addition, the following International Organization for Standardization (ISO) standard was also considered in the development/update of this RG:

- ISO 17873: 2004 "Nuclear facilities ─ Criteria for the design and operation of ventilation systems for nuclear installations other than nuclear reactors" (Ref. 17)

This RG incorporates similar design and performance guidelines as provided in the IAEA documents and ISO standard and is consistent with the safety principles provided in these publications.

Documents Discussed in Staff Regulatory Guidance

This RG endorses the use of one or more codes and standards developed by external organizations as third-party guidance documents. These codes, standards and third-party guidance documents 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.

C. STAFF REGULATORY GUIDANCE

This section includes the staff regulatory guidance for evaluating the habitability of a NPP CR during a postulated hazardous chemical release. Any hazardous chemical stored on site within a half (½) kilometer (km) [1,640 feet (ft)] of the CR in a quantity greater than 45 kilograms (kg) [(100 pounds (lb)] should be considered for CR habitability evaluation. Hazardous chemicals should not be stored within 0.1 km (330 ft) of a CR or its fresh air inlets, including ventilation system intakes and locations of possible infiltration such as penetrations. Licensees are encouraged to conduct periodic surveys of stationary and mobile sources of hazardous chemicals near their plant sites to keep the site-specific inventories up to date. However, this RG also provides essential assumptions and criteria for screening out release events that need not be considered in the evaluation of CR habitability. The following criteria identify the release events that need not be considered further for CR habitability evaluation.

1. Hazard Screening

Whether a chemical source (stationary or mobile) constitutes a hazard that requires a CR habitability evaluation depends on prevailing meteorological conditions, the inleakage characteristics of the CR, and the air concentration in the CR as compared to the applicable toxicity concentrations shown in Table 1 and the combination of the weight quantity of chemical and the distance from the plant shown in Table 2.

1.1 Exemption Criteria for Stationary Sources

Chemicals stored or situated at distances greater than 5 miles from the plant need not be considered because, if a release occurs at such a distance, atmospheric dispersion will dilute and disperse the incoming plume to such a degree that either toxic limits will never be reached or there would be sufficient time for the CR operators to take appropriate action. In addition, small quantities (i.e., less than 10 kg) for laboratory use in the plant can be exempt.

In addition, the maximum allowable inventory in a single container should be stored at specified distances beyond 0.1 km from the CR (e.g., its fresh air inlet) and varies according to the distance and the CR type, as specified by CR air change per hour (ACH) rates in Table 2. If there are several chemical containers, the evaluation normally considers only the failure of the largest container unless the containers are interconnected in such a manner that failure of a single container could cause a release from several containers.

1.2 Screening Criteria for Mobile Source Chemicals

For the chemicals in Table 1, known or projected to be present in either stationary form or in mobile form by rail, water, or road routes within an 8 km radius of a NPP, a CR habitability evaluation may be considered based on both Table 1 and Table 2 screening values. The Table 2 variables were established under Category F Pasquill stability class[2] and at a fixed 50 mg/m^3 concentration value. They are adjustable parameters needed for determining the total quantity (i.e., the minimum chemical's weight) of the mobile sources and the seven tiers of incremental distance described in Table 2. The first column of Table 2 contains radii between 0.3 and 5 miles from the CR, and the three columns to the right list the calculated weights for three ACH values.

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[2] "Pasquill stability class" is a meteorological classification method for categorizing atmosphere stability and is defined by, among other things, the regional conditions of wind speed, solar radiation during the day, and cloud cover during the night. See https://www.ready.noaa.gov/READYtools.php for more information.

Table 1. Selected IDLH Values for Twenty-Nine Hazardous Chemicals

Chemical	*ppm*(a)	*mg/m^3* (b)	Chemical	*ppm*	*mg/m^3*
Acetaldehyde	2,000	3,600	Fluorine	25	50
Acetone	2,500	6,000	Formaldehyde	20	24
Acrylonitrile	85	149	Halon 1211	20,000	
Anhydrous ammonia	300	210	Halon 1301	50,000	
Aniline	100	380	Helium	asphyxiant	
Benzene	500	1,600	Hydrogen cyanide	50	55
Butadiene	2,000	4,400	Hydrogen sulfide	100	150
Butene	asphyxiant		Methyl alcohol	6,000	7,800
Carbon dioxide	40,000	7,360	Nitrogen (liquid or compressed)	asphyxiant	
Carbon monoxide	1,200	1,320			
Chlorine	10	30	Sodium oxide		2
Ethyl chlorine	3,800	9.880	Sulfur dioxide	100	520
Ethyl ether	1,900	5,700	Sulfuric acid		15
Ethylene dichloride	50	200	Vinyl chloride	1,000	2,600
Ethylene oxide	800	720	Xylene	900	3,915

(a). Parts of vapor or gas per million parts of air by volume at 25 °Celsius and 760 torr (standard temperature and pressure).

(b). Approximate milligrams of chemicals per cubic meter (mg/m^3) of air, at standard temperature and pressure, based on listed ppm values. To convert ppm to mg/m^3, multiply the "ppm" value with the chemical's molecular weight (i.e., gram/mole) and divide by the universal standard temperature and pressure gas constant, 24.45.

Table 2. Minimum Chemical Weights That Require Consideration in CR Habitability Evaluation(a)

Distance from CR in Mile (km)(b)	ACH 0.015(c)	ACH 0.06	ACH 1.2
0.3 (0.5) to 0.5 (0.8)	4.1(d)	1.0	0.050
0.5 (0.8) to 0.7 (1.1)	16	4.0	0.20
0.7 (1.1) to 1.0 (1.6)	55	14	0.68
1 (1.6) to 2 (3.2)	123	31	1.5
2 (3.2) to 3 (4.8)	590	150	7.4
3 (4.8) to 4 (6.5)	1,680	420	21
4 (6.5) to 5 (8.0)	4,000	1,000	50

(a) The table is adapted from RG 1.78, Rev. 1 (2001) and added with SI units.

(b) Values in parenthesis are in unit kilometer (km).

(c) An ACH of 0.015 (i.e., 0.015 of the control room air by volume is replaced by atmospheric ambient air in one hour) is considered representative of a "tight" CR that has very low leakage construction features and automatic isolation capabilities. ACH of 0.06 is considered representative of a CR that has normal leakage construction features and automatic isolation capabilities, whereas an ACH of 1.2 is considered representative of the CR with construction features that are not as efficient for leakage control and without automatic isolation capabilities.

(d) Storage weights, in unit of metric ton (i.e., 2,205 lb) are obtained based on a 50 mg/m^3 concentration and Category F Pasquill Stability Class.

The evaluation of CR habitability should consider estimates of the frequencies for shipments that are within 8 km radius of a NPP. The NRC considers shipments to be frequent if there are 10 total shipments per year for truck traffic, 30 total shipments per year for rail traffic, or 50 total shipments per year for barge traffic. These frequencies are based on transportation accident statistics, conditional spill probability given an accident, and a limiting criterion for the number of spills from NUREG/CR-6624. Therefore, the technical basis for Table 2 in this RG is the same as that of RG 1.78, Revision 1.

Therefore, mobile sources need not be considered further if the total shipment frequency for all hazardous chemicals, i.e., all hazardous chemicals considered as a singular cargo category without further distinction of the nature of these chemicals, does not exceed the specified number by traffic type. Frequent shipments, i.e., shipments exceeding the specified number by traffic type, need not be considered in the analysis if the quantity of hazardous chemicals is less than the quantity shown in Table 2 (adjusted for the appropriate toxicity limit, meteorology, and ACH in the CR).

2. Risk Evaluation

Releases of hazardous chemicals from stationary sources or from frequently shipped mobile sources in quantities that do not meet the screening criteria in the Sections C.1.1 or C.1.2 above should undergo detailed analyses for CR habitability. Licensees may provide risk information to demonstrate that the radiological risk to the public from such toxic chemical releases is small, consistent with the Commission's Safety Goal Policy Statement, SECY-00-0077, "Modifications to the Reactor Safety Goal Policy Statement," dated March 30, 2000 (Ref. 18). Releases of toxic chemicals that could potentially result in a significant concentration in the CR need not be considered for further detailed evaluation if the releases occur at a frequency of $1x10^{-6}$ per year or less because the NRC considers these resultant low levels of radiological risk to be acceptable.

To facilitate risk-informed license amendments, risk information should be provided in accordance with the guidance set forth in RG 1.174. As explained in RG 1.174, one key principle in risk-informed regulation is that proposed increases in risk are small and consistent with the intent of the Commission's Safety Goal Policy Statement. The safety goals and associated quantitative health objectives (QHOs) define acceptable level of risk as a small fraction (0.1%) of other risks to which the public is exposed. Procedures outlined in the "Framework for Risk-Informed Changes to the Technical Requirements of 10 CFR Part 50," an attachment to SECY-00-0198 (Ref. 19), may also be used as guidelines for quantifying risks. If the level of risk associated with the release of a toxic chemical is not acceptable, then a detailed CR habitability evaluation should be performed. A method acceptable to the NRC staff for evaluating the CR habitability is described in Section C.3 below.

3. Control Room Habitability Evaluation

When performing a detailed evaluation of CR habitability during a hazardous chemical release using this guidance, the metric applicants and licensees should use for each chemical is the IDLH that can be tolerated without physical incapacitation of a CR operator. In deriving the toxicity level in the CR, the detailed calculations should consider several factors, such as accident type; release characterization (e.g., release rate, duration); atmospheric dispersion characteristics, including prevailing meteorological conditions at the site; and the air exchange rate of the CR. The checklist for the determinations of the toxicity level (i.e., concentration) in the CR, based on the toxic chemical and CR air quality parameter values, is as follows: (1) name of the most hazardous chemical, (2) type of source (stationary or mobile) during the accidental release; (3) maximum quantity or concentration measured (if available); (4) IDLH values (i.e., ppm or mg/m^3); (5) average continuous release rate of hazardous chemical; (6) vapor pressure (torr) of hazardous chemical (at local ambient plant temperature); (7) fraction of chemical flashed and rate of boiloff when spilling occurs; (8) total plume travel distance between the CR and the chemicals; and (9) local meteorological data.

For determining the air quality in the CR for habitability evaluation, the NRC recommends the following 7 considerations: (1) the design height of air intake windows; (2) the volume size of CR; (3)

the air-exchange rate of CR; (4) the flow rate as cubic feet per minute of the CR; (5) the unfiltered makeup or inleakage air for the CR; (6) the filtered makeup and recirculated air under normal and emergency operations; and (7) the use of a filtered nuclear air-cleaning system or personal breathing-air supplying device during an emergency.

3.1 IDLH Concentrations

Table 1 presents the IDLH values as maximum toxic concentrations for the selected 29 chemicals. This table lists commonly encountered chemicals, but the list is not all-inclusive. A more complete list of chemicals is in NUREG/CR-6624. An unprotected operator should not stay in a CR with chemical concentrations exceeding those in Table 1 for longer than 2 minutes.

3.2 Accident Types and Release Characteristics

Two types of industrial accidents should be considered for each source of hazardous chemicals: maximum concentration chemical accidents (MCAs) and average concentration-duration chemical accidents (ACAs).

MCAs result in a short-term puff or instantaneous release of a large quantity of hazardous chemicals. An example of this type of accident would be the failure of a manhole cover on the chemical container or the outright failure of the container itself. Such a failure could occur during transport of a container from a handling mishap or from naturally or accidentally produced environments such as earthquakes, flooding, fire, explosive overpressure, or missiles. A significant inventory could be released right away, with the balance releasing over an extended period. Under MCAs, the analysis should consider: (1) the largest storage container within the guidelines of Table 2 located at a nearby stationary facility; (2) the largest shipping container within the guidelines of Table 2 that is frequently transported near the site; or (3) the largest container stored on site. For multiple shipping containers of equal size, the evaluation should consider failure of only one container unless the failure of that container could lead to successive failures. For the largest container stored on site, the evaluation should consider the total release from this container unless the containers are interconnected in such a manner that a single failure could cause a release from several containers.

ACAs result in a long-term, low-leakage-rate, continuous release. Most onsite chlorine releases experienced to date within NPPs have been ACAs, involving leakage from valves or fittings and resulting in a long-term release with a leakage rate from near zero to less than 1 pound of chlorine per second. Given warning, the CR operator needs only a breathing apparatus to be protected from ACAs. However, because such a release might continue unabated for many hours, a self-contained breathing apparatus, a tank source of air with manifold outlets, or equivalent protection capable of operation for an extended period should be available. For example, the continuous release of hazardous chemicals from the largest safety relief valve on a stationary, mobile, or onsite source within the guidelines of Table 2 should be considered.

For both types of accidents, MCAs and ACAs, the evaluation should consider release of contents during an earthquake, tornado, or flood for chemical container facilities that are not designed to withstand these natural events. In the evaluation of CR habitability, it may also be appropriate to consider hazardous chemical releases coincident with the radiological consequences (e.g., a design-basis loss-of-coolant accident for plants that are vulnerable to both events simultaneously) and demonstrate that such coincident events do not produce an unacceptable level of risk.

3.3 Atmospheric Dispersion

NUREG/CR-6210 documented that HABIT has two basic Fortran modules, i.e., EXTRAN and CHEM. The EXTRAN module is formulated for a Gaussian plume or puff dispersion model and longitudinal, lateral, and vertical dispersions between the point of release to the intake of the CR. The CHEM module is calculated for the chemical concentration and exposure in the CR based on the ventilation system and associated air-cleaning installations. The EXTRAN also allows for the effect of building wakes and for additional dispersion in the vertical direction when the distance between the release point and the CR is small. When boiloff or a slow leak is analyzed, the effects of density on vertical diffusion may be considered if adequately substantiated by reference to data from experiments.

For chemicals that are not gases at 100 degrees Fahrenheit at normal atmospheric pressure but are liquids with vapor pressures in excess of 10 torr, applicants and licensees should consider the rate of flashing and boiloff to determine the rate of release to the atmosphere and the appropriate time duration of the release. For gases that are heavier than air, the buoyancy effect should be considered for many parameters, such as density of the plume and roughness of the ground surface, in determining the dispersion characteristics. NUREG-2244, “HABIT 2.2: Description of Models and Methods,” incorporates both the U.S. Environmental Protection Agency’s DEnse GAs DISpersion Model (DEGADIS) code (Ref. 20) and the U.S. Department of Energy’s atmospheric dispersion model “SLAB” code (Ref. 21) for denser-than-air releases codes for dense gas transport phenomena.

3.4 Control Room Air Flow

The evaluation should consider the air flows for infiltration, makeup, and recirculation for both normal and accident conditions. It should also consider the volume of the CR and all other rooms, including the ventilation systems, that share the same ventilating air during both normal and accident conditions.

The CR envelope should be constructed and equipped with a low-leakage ventilation system to stop or reduce inleakage. For example, low-leakage dampers, low-leakage shut-off valves and other low-leakage Heating, Ventilation and Air Conditioning (HVAC) components should be installed on the upstream side of recirculation fans or at locations where negative pressure exists (e.g., fan shaft seals).

The inleakage characteristics of the CR envelope during a hazardous chemical challenge should be determined by testing. A comprehensive test of the CR ventilation systems will identify the total inleakage associated within the CR envelope but will not necessary identify all inleakage sources. An effective and NRC staff-accepted method to test CR envelope inleakage is American Society of Testing and Materials (ASTM) Standard E741, “Standard Test Method for Determining Air Change in a Single Zone by Means of a Tracer Gas Dilution” (Ref. 22). Further, if credit has been taken in the evaluation for the removal of hazardous chemicals by filtration, adsorption, or other means, the applicant or licensee should provide a technical basis for the dynamic removal capability of the removal system considered.

4. Protection Measures

For adequate safety and protection of the CR operators against the types of accidental releases discussed in Section 3.2 above, the plant design should include features to: (1) provide capability to detect such releases; (2) isolate the CR if there is a release; (3) make the CR sufficiently leak tight; and (4) provide equipment and procedures for ensuring that the CR operators have access to breathable air, proper PPE, or both. Provisions that are adequate for the large, instantaneous release should also provide protection against the low-leakage-rate release. Section 3.4 provides the guidance related to making the CR sufficiently leak tight. The implementation of chemical safety and protection measures may be excluded if the detailed evaluation of CR habitability shows that the highest concentration predicted in the CR is below the IDLH value. Otherwise, licensees may select and implement specific protection measures based on the design features of their facilities.

4.1 Detection System

The detection system should be able to detect and signal a concentration level that is significantly lower than the IDLH value, for example, a concentration level of 5 ppm for chlorine with an IDLH value of 10 ppm. The detection system should be qualified for all expected environments, including severe environments. The system should also be designated as seismic Category I and be qualified as such in accordance with the guidance in the second paragraph of Section 4.2 to address this issue. The installation of the detectors should ensure that they are protected from adverse temperature effects. The manufacturer's guideline for maintenance, testing, and calibration, as well as adjustment to such guideline made by licensees, are acceptable provided they follow sound engineering practices and are compatible with the proposed application.

If neither toxic information nor detection instruments are available, human detection, such as unpleasant smell, burning odor, irritated eyes, and choking, may be useful as a warning of a dangerous condition and a signal to don PPE.

Quick-response detectors should be placed in the fresh air inlets (both normal and emergency air intakes). Depending on the design, it may also be appropriate to have separate channels of detectors for fresh air inlets and to have detectors in the CR envelope ventilation system recirculation lines. The system response time, which incorporates the detection response time, the valve closure time, and associated instrument delays, should be less than or equal to the required isolation time based on the IDLH value.

Remote detectors may be located at storage and unloading locations. These detectors may be placed, and the detector trip points adjusted, to ensure detection of either a leak or a container rupture. A detector trip signal should isolate the CR before toxic chemical concentration within the CR exceeds the chemical's IDLH value. The detector trip signal should also set off an alarm and provide a readout in the CR. An alternative to the installation of remote detectors would be an isolation system that uses local detectors with a very short isolation time.

4.2 Isolation System

The evaluation should consider the capability to close the CR air ducts with dampers and thus isolate the CR. For onsite storage, measures should be in place to manually isolate the CR. Upon detection of a toxic chemical, a detector should initiate complete closure of isolation dampers to the CR with minimal delay. The isolation time is a function of the CR design, in particular, the inleakage characteristics. If the detectors are upstream from the isolation dampers, then credit will be allowed for the travel time between the detectors and the dampers.

The isolation system and its components, the recirculating filter system, and the air conditioning system should meet Institute of Electrical and Electronics Engineers (IEEE) Standard 603-2018, "IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations" (Ref. 23), since these systems are needed to maintain a habitable environment in the CR during a design-basis accident.

For plants that isolate CRs, steps should be taken to ensure that the isolated exchange rate is not inadvertently increased by design or operating error. Ventilation equipment for the CR and for the adjacent zones should be reviewed to ensure that enhanced air exchange between the isolated CR and the outside will not occur. All doors leading to the CR should be kept closed when not in use.

4.3 Protection System

If the evaluation of possible accidents for any hazardous chemical indicates that the applicable toxicity limits may be exceeded in the CR, measures should be in place to provide adequate protection to CR operators. The evaluation should consider the use of full-face, self-contained, pressure-demand-type breathing apparatus (or the equivalent) and protective clothing. Adequate air capacity for the breathing apparatus (at least 6 hours) should be readily available on site to ensure that at least 6 hours is available to transport additional bottled air from offsite locations. This offsite supply should be capable of delivering several hundred hours of bottled air. The units of breathing apparatus should be enough for the emergency crew or staff working in the CR.

Storage provisions for breathing apparatus and procedures for their use should be such that operators can begin using the apparatus within 2 minutes after detection of a hazardous release. Breathing apparatus, air supply equipment, and protective clothing should meet the criterion that a single toxic gas event would not render nonfunctional the total inventory of such protective equipment.

4.4 PPE Training

CR operators should train and have the ability to don a respirator and associated PPE within 2 minutes. The interpretation of IDLH value is considered appropriate since it provides an adequate margin of safety as long as CR operators use protective measures within 2 minutes after detection of hazardous chemicals.

5. Emergency Planning

The licensee should initiate CR emergency procedures as described in NUREG-0696, "Functional Criteria for Emergency Response Facilities, Office of Inspection and Enforcement," issued February 1981 (Ref. 24), if a hazardous chemical release occurs within or near the plant. These procedures should address both ACA and MCA and should identify the most probable chemical releases at the station. The procedures should discuss methods of detecting the event by station personnel, both during normal workday operation and during minimum staffing periods (e.g., late night and weekend shift staffing). Special instrumentation provided for the detection of hazardous chemical releases should be described, including the action initiated by the detecting instrument and the level at which this action is initiated. The emergency procedures should describe the isolation of the CR, the use of protective breathing apparatus or other protective measures, and maintenance of the plant in a safe condition, including the capability for an orderly shutdown or scram. Finally, the procedure should describe criteria and procedures for evacuating nonessential personnel from the station.

Emergency planning should include training emergency planning personnel on the use of instruments. It should also include periodic drills on the procedures.

Arrangements should be made with Federal, State, and local agencies or other cognizant organizations for the prompt notification to the NPP when accidents involving hazardous chemicals have occurred within 5 miles of the plant.

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. 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.

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4. CFR, "Standards for Protection against Radiation," Part 20, Chapter 1, Title 10, "Energy."

5. U.S. Nuclear Regulatory Commission (NRC), Regulatory Guide (RG) 1.91, "Evaluations of Explosions Postulated to Occur on Transportation Routes Near Nuclear Power Plants." Revision 2, Washington, DC.

6. NRC, RG 1.174, "An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis," Washington, DC.

7. NRC, RG 1.189, "Fire Protection for Nuclear Power Plants," Washington, DC.

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[3] Publicly available NRC published documents are available electronically through the NRC Library on the NRC's public Web site at http://www.nrc.gov/reading-rm/doc-collections/ and through the NRC's Agencywide Documents Access and Management System (ADAMS) at http://www.nrc.gov/reading-rm/adams.html.The documents can also be viewed online or printed for a fee in the NRC's Public Document Room (PDR) at 11555 Rockville Pike, Rockville, MD. For problems with ADAMS, contact the PDR staff at 301-415-4737 or (800) 397-4209; fax (301) 415-3548; or e-mail pdr.resource@nrc.gov.

14. NRC, Management Directive (MD) 6.6, “Regulatory Guides,” Washington, DC, May 2, 2016 (ADAMS Accession No. ML18073A170).

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19. NRC, SECY-00-0198, “Status Report on Study of Risk-Informed Changes to the Technical Requirements of 10 CFR Part 50 (Option 3) and Recommendations on Risk-Informed Changes to 10 CFR 50.44 (Combustible Gas Control),” Washington, DC, September 2000. (ADAMS Accession No. ML003747699).

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23. Institute of Electrical and Electronics Engineers (IEEE), Standard 603, “Criteria for Safety Systems for Nuclear Power Generating Stations,” IEEE Power and Energy Society, Piscataway, NJ, 2018.[7]

24. NRC, NUREG-0696, “Functional Criteria for Emergency Response Facilities,” Office of Inspection and Enforcement, Washington, DC, February 1981. (ADAMS Accession No. ML051390358).

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[4] Copies of IAEA documents may be obtained through the IAEA Web site, http://www.IAEA.org, or by writing the International Atomic Energy Agency, P.O. Box 10 Wagramer Strasse 5, A-1400, Vienna, Austria.

[5] Copies of ISO documents can be purchased from the ISO Customer Care: customerservice@iso.org

[6] Copies of ASTM documents may be obtained by writing ASTM Headquarters, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, or via email at service@astm.org

[7] Copies of IEEE documents may be obtained from the IEEE Service Center, 445 Hoes Lane, Piscataway, NJ 08855-1331.

25. NRC, Management Directive 8.4, “Management of Backfitting, Forward Fitting, Issue Finality, and Information Requests,” Washington, DC, September 20, 2019. (ADAMS Accession No. ML18093B087).

APPENDIX A

PROCEDURE FOR CALCULATING WEIGHTS OF HAZARDOUS CHEMICALS NECESSITATING THEIR CONSIDERATION IN HABITABILITY EVALUATIONS

This appendix describes a simplified multiplication or division procedure to adjust the distance/weight relationships for specific chemical toxicities (i.e., IDLH value), CR airflow rates, and for varying Pasquill stability classes, assuming that the transport of material is moving with the wind directly from the release point to the air intake.

The weights presented in Table 2 of this RG were generated from the EXTRAN computer code without the wake-effect correction, based on the following assumptions:

- An IDLH value of 50 milligrams per cubic meter (mg/m^3)
- CR air exchange hourly rates (i.e., ACH) of 0.015, 0.06, and 1.2
- Category F Pasquill stability class

If the IDLH value, air exchange rate, or meteorological conditions differ from the assumptions used in Table 2, simplified relationships can be used to determine the new weights guidance of hazardous chemicals that are to be considered for the CR habitability evaluation using Table 2 directly.

Varying IDLH Concentration

The weights presented in Table 2 are directly proportional to the toxicity concentration; that is, the total chemical weights increase when IDLH value increase. If a chemical had an IDLH of 500 mg/m^3, then the allotment of weights in Table 2 (based on 50 mg/m^3) should increase by a factor of 10.

Varying Air Exchange Rate

The weights in Table 2 are inversely proportional to the ACH; that is, the total chemical weights decrease when the ACH increases. If a CR has an ACH of 2.4, then the weights from Table 2 (based on an ACH of 1.2 per hour) decrease by a factor of two. In other words, the weights are appropriately adjusted for the actual fresh-air exchange rate. CRs with automatic isolation capabilities may have leakage characteristics different from those listed in Table 2. Again, appropriate adjustments of weight should be made based on the actual air exchange rate. The use of an ACH less than 0.06 should have a periodic test to validate the low leakage rate.

Varying Metrology Stability Category

Varying meteorology stability category is not a linear extrapolation like the examples above. Three weighting factors are provided in Table A-1. If the meteorology was out of the Category F condition, for better (i.e., Category E) or for worse (i.e., Category G), then the tabulated values 2.5 and 0.4 could be used for adjusting the new weight limiting value for Table 2.If there is no change from Category F condition, then the multiplication factor is a unity. Note that in RG 1.78, Revision 1,the Category F Pasquill stability class did represent the worst 5th-percentile meteorology observed at the majority of the NPP sites.

Table A-1. Factors for Varying Meteorology Category

Pasquill Stability Category	Weighting Factor
A	--
B	--
C	--
D	--
E	2.5
F	1
G	0.4

There are no relevant constant or variable factors for Categories from A to D. Please consult with the local meteorologist if desired.