NATURAL PHENOMENA HAZARDS IN FUEL CYCLE FACILITIES

Purpose

The staff is issuing this interim staff guidance (ISG) to provide additional guidance for evaluating accident sequences that may result from natural phenomena hazards (NPH) as required under Title 10 of *the Code of Federal Regulations* (10 CFR) Part 70, "Domestic Licensing of Special Nuclear Material," Subpart H, "Additional Requirements for Certain Licensees Authorized To Possess a Critical Mass of Special Nuclear Material." This guidance provides criteria and methods that the staff can use to review the treatment of NPH at fuel cycle facilities as evaluated in the facility integrated safety analysis (ISA).

Regulatory Framework

For facilities regulated under 10 CFR Part 70, Subpart H, 10 CFR 70.62(c)(1) requires, in part, that each licensee conduct and maintain an ISA that is of appropriate detail for the complexity of the process and that identifies, among other things, "potential accident sequences caused by process deviations or other events internal to the facility and credible external events, including natural phenomena." The regulations in 10 CFR 70.62(c)(1) also require, in part, that each licensee or applicant identify the consequence and the likelihood of occurrence of each potential accident sequence and the methods used to determine the consequences and likelihoods.

The regulations in 10 CFR 70.61, "Performance Requirements," requires, in part, that individual accident sequences resulting in high consequences to workers and the public be "highly unlikely" and that sequences resulting in intermediate consequences to these receptors be "unlikely."

For new facilities or new processes at existing facilities, 10 CFR 70.64(a)(2), "Natural phenomena hazards," requires that the design must provide for adequate protection against natural phenomena with consideration of the most severe documented historical events for the site.

Discussion

As a result of the lessons learned from the accident at the Fukushima Dai-ichi nuclear power station, the U.S. Nuclear Regulatory Commission (NRC) staff performed a systematic evaluation and inspection of selected fuel cycle facilities to (1) confirm that licensees are in compliance with regulatory requirements and facility-specific license conditions; and (2) to evaluate their readiness to address NPH events and other licensing basis events related to NPH. From December 2011 through May 2012, the staff conducted these inspections in accordance with NRC Temporary Instruction (TI) 2600/015, "Evaluation of Licensee Strategies for the Prevention and/or Mitigation of Emergencies at Fuel Facilities."

As a result of the TI inspection activities, the staff identified unresolved items (URI's) related to 10 CFR Part 70 requirements with regards to the justification and documentation of the assumptions used in the ISA for NPH. The URIs document the need to further evaluate whether licensees are in compliance with regulatory requirements regarding accident sequences resulting from natural phenomena events. The staff is issuing this ISG to provide additional guidance for addressing accident sequences that may result from NPH. This ISG will be incorporated into future revisions of Appendix D of Chapter 3 of NUREG 1520, "Standard

Review Plan for the Review of a License Application for a Fuel Cycle Facility." Specific emphasis was provided on seismic hazards due to recent events such as the Fukushima Dai-ichi accident and recent updates to the U.S. Geological Survey hazard curves.

<u>Consideration of NPH in ISA of Existing Fuel Cycle Facilities</u>

The majority of existing operating fuel cycle facilities were designed and constructed over the last 60 years. As discussed further below, the design and construction of fuel cycle facilities was often based on consensus codes and standards applicable at the time the facility was constructed. Accordingly, there is often wide variation in the design provisions used to address natural phenomena. The design provisions range from no specific seismic requirements, to requirements based on codes and standards used for commercial construction, to requirements based on codes and standards used for nuclear facilities. For example, some structures at existing fuel cycle facilities were built to a building code with design-basis earthquake having exceedance probabilities of $2x10^{-3}$ per year to less than $1x10^{-3}$ per year. The current building code uses ground motions with a $4x10^{-3}$ annual exceedance probability.

Additionally, implementation of 10 CFR Part 70 requirements for existing facilities may vary because of different definitions of likelihood proposed by licensees to comply with 10 CFR 70.65(b)(9). Chapter 3 of NUREG 1520 describes the acceptance criteria for licensee- and applicant-proposed definitions of the terms highly unlikely and unlikely as they apply to the development and maintenance of the ISA. The staff review should include an assessment of the implementation of the definitions of likelihood in the ISA for natural phenomena events. The staff's review should focus on ensuring that the definitions are consistent with the standard practice associated with each natural phenomena event. The implementation of the definitions of highly unlikely and unlikely may differ for each natural phenomena event, as applicable. However, there are several factors that should be considered when evaluating how licensees both define and implement unlikely and highly unlikely for natural phenomena events within the ISA. This is because there is no common approach to determine how probabilistic hazards are determined for various natural hazard phenomena and because different natural phenomena present a unique set of hazards to each facility. Therefore, the resulting performance of the facility under the various NPH and the contribution to overall risk should be considered.

For example, flooding hazards are often described in terms of a 1-percent chance of being equaled or exceeded in any given year (100-year) or a 0.2-percent-annual-chance (or 500-year) flood. The evaluation in the ISA could then use these probable maximum flood levels as the design basis for the facility to demonstrate compliance with the regulatory requirements. Flooding levels below a design probable maximum flood may not contribute to an increase in facility risk (e.g., flood waters will remain contained behind a designed flood wall or below the grade elevation of the facility). In contrast, standard building codes and standards require seismic designs based on probabilistic ground motions with 10 percent probability of exceedance in 50 years or 2 percent probability of exceedance in 50 years. This greater level of scrutiny is warranted because seismic ground motions can adversely affect a much broader range of facility components, from concrete or steel structures to piping or electrical hardware, and because these components may fail over a rather broad range of seismic ground motions.

The majority of existing operating fuel cycle facilities completed their ISAs after Subpart H of 10 CFR Part 70 was promulgated[1] in September 2000. These ISAs, in general, postulated that

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[1] Refer to 10 CFR 70.62(c)(3) which requires, in part, that existing licensees submit for NRC approval, by April 2001, a plan that describes the ISA approach; and by October 2004, or in accordance with the

structures, systems and components (SSCs) will remain intact during credible seismic events and, in some cases, concluded that a high radiological or chemical consequence was highly unlikely based on the assumption that the SSCs will adequately perform their safety functions during postulated NPH events. The staff should review the basis for the assumptions used in the ISA to ensure that adequate documentation (e.g. design calculations) exists to support the expected performance of SSCs and/or potential consequences of failures of SSCs.

The license application and ISA should address natural phenomena events (e.g., tornadoes, hurricanes, and earthquakes) and other external events with a sufficient level of detail to characterize and assess their impact on facility safety. The licensee's assessment should identify the licensing assumptions and the design bases for the SSCs credited for prevention or mitigation of the consequences to the facility for these types of events. The licensee's assessment should indicate which events are considered to be not credible and the basis for that determination. It should also indicate which events could occur without adversely impacting safety and the basis for that determination. In order to comply with the regulatory requirements to prevent or mitigate the consequences of NPHs, licensees may need to maintain access to or possess equipment that is capable of limiting the consequences to public and worker health and safety in the event of multiple credible challenges and degraded or disabled resources. This could include long-term loss of functions, such as offsite power, onsite emergency power, offsite water supply, other offsite services, and transportation to access offsite resources.

In order to meet the requirements of 10 CFR 70.62(c)(1), licensees should also evaluate events not previously included as part of the design basis in the ISA if current information about NPHs indicates that the events are credible. The staff's review should validate the assumption that the licensing and design basis and the underlying data and assumptions are appropriate to the current condition of the facility, and that the site and the facility are in compliance with their design and licensing basis and the regulations.

<u>Graded Approach to Consideration of NPH in the ISA</u>

The use of a graded approach to demonstrate compliance with applicable regulatory requirements is outlined in Appendix B of Chapter 3 of NUREG-1520 as it relates to the ISA. A graded approach recognizes the diversity of regulated facilities and processes, potential hazards, and safety functions needed to prevent accident sequences and/or mitigate the consequences of events from NPH. A graded approach can be used by applicants and licensees to place SSCs into different categories such that the required level of analysis, the complexity of the design or evaluation approach, documentation, and actions are commensurate with:

- The relative importance to safety of the structure or component or the amount of risk reduction attributed to the structure or component to meet the performance requirements;
- The particular characteristics of the structure or component, and the complexity and potential consequences that could result in the event of failures; and
- The magnitude of the NPH.

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approved plan, a completed ISA. It also required licensees to identify performance deficiencies and to correct them with adequate compensatory measures.

For example, the objective of building codes and standards for NPH protection is to prevent structural collapse or failures that could endanger lives or prevent safe egress of personnel. The primary concern at regulated facilities, after meeting the life safety objective, is how failures of components can affect regulated material, affect mitigation measures and produce releases that lead to consequences that exceed the performance requirements of 10 CFR Part 70. By using a graded approach, licensees can assign different performance objectives to SSCs ranging from:

- Preventing loss of structural integrity that could endanger life safety;
- Preventing loss of capability to perform functions important to safety during and/or after the earthquake that could lead to consequences to the public and/or worker;
- Confining hazardous material.

<u>Evaluation of Structures and Components at Existing Facilities</u>

At existing facilities, licensees' safety analyses or licensing and design bases may change as a result of updated building codes and standards that consider NPHs as credible. Licensees may find that:

1. SSCs were designed and constructed without adequate NPH design and construction standards.
2. The function of the SSC changed to an item relied on for safety (IROFS) during the ISA evaluation.
3. There is an increased likelihood (e.g. hazard curves) or consequence attributed to/related to an NPH that was not previously understood or known.
4. Addition, modification, or deterioration has led to significant physical change in an SSC that can affect its intended safety function.
5. Occurrence of an NPH, especially an earthquake, may affect multiple or all SSCs in a facility. This could lead to multiple common cause failures.

Many existing fuel cycle facilities were designed and constructed using applicable building codes and standards adopted by State or local authorities. These building codes and standards established minimum requirements for providing safety to life and property from seismic hazards. This goal of providing safety of life and property is accomplished through the specification of prescriptive criteria to achieve adequate performance of a structure to ensure its capability to withstand a defined intensity of earthquake ground motions. The development of seismic design criteria is an ongoing process of improvement which is reflected in the evolution of seismic criteria in building codes and standards. Facilities designed and constructed with building codes and standards that contained criteria for seismic loads resulting from earthquakes having accelerations associated to 10 percent probability of exceedance in 50 years. These facilities, for the most part, if adequate design calculations and documentation exists, can demonstrate that their SSCs will adequately perform with a low likelihood of structural collapse under the specified accelerations.

On the other hand, some fuel cycle facilities were designed and built to a building code that did not prescribe criteria for seismic hazards. For example, most facilities built in the eastern United States were designed without consideration of potential earthquake hazards. If licensees have not previously considered seismic hazards as part of their design or ISA, the licensee may be able to make an assessment using the as-built condition of the facility. This assessment includes a review of existing documentation such as drawings and construction specifications to identify as-built characteristics of the SSCs. The review can identify valuable information such as properties of materials used in construction, structural systems used, and elements that can affect seismic performance. Walk-downs of the facility can identify and confirm as-built data gathered as well as identify deviations from original drawings. From walk-downs, the licensee can identify and provide special emphasis on components that can affect operations with hazardous materials.

The licensee can select an evaluation basis seismic hazard to serve as the input to the seismic evaluation. The evaluation basis event should consider conditions at the site such as soil properties and local seismicity. If an evaluated SSC has a deficiency in that it does not meet the criteria under the selected hazard, several options should be considered by the licensee:

- Conduct a more rigorous evaluation of the deficiencies to account for potential conservatism not accounted for in the simplified evaluation;
- Retrofit the SSC to improve resistance to the selected hazard;
- Modify usage of the SSC to eliminate the hazards;
- Incorporate a combination of mitigation/prevention strategies to reduce the materials at risk (seismic isolation valves, bunkers, etc.).

A prioritization or graded approach can serve as a decision tool to identify how deficiencies will be corrected. For example, aspects of the load bearing elements of the building structure that house hazardous material may be evaluated further using more complex methodologies. However, for secondary SSCs or items that indirectly contribute to seismic performance, it may be less expensive or time-consuming to retrofit rather than perform a detailed analysis. In addition, using the prioritization approach, the licensee can provide a plan to retrofit or perform detailed analyses of critical SSCs first and then provide a plan with a schedule to evaluate secondary SSCs subsequent to the primary SSCs.

<u>Performance-Based Seismic Design and Evaluation</u>

Licensees can demonstrate how their facility meets the performance requirements of 10 CFR 70.61 by using analytical methods to demonstrate the performance of the SSCs in the facility and how failures of those SSCs may lead to consequences of concern. Demonstration of performance can be done by selecting performance objectives that combine a desired performance level with a specified earthquake hazard. The performance objectives are consciously established by licensees and applicants by taking into consideration the radiological and chemical consequences of failures of SSCs. The concept of performance objectives is used widely in building codes and standards, such as the International Building Code, and standards for nuclear facilities such as American Nuclear Society (ANS) 2.26, “Categorization of Nuclear Facility Structures, Systems, and Components for Seismic Design.” Seismic design calculations from building codes and standards are aimed at providing a low risk of earthquake-related death or life threating injuries from a collapse of structures. Other considerations in evaluating facilities for NPH include:

- Common cause failures;

- Proper assignment of an SSC performance goal with adequate construction methods based on accepted standards that provide acceptably low risk;

- Defined seismic design categories and limit states that are adequately supported by analyses (graded approach);

- Documented qualitative or quantitative values of the critical design parameters at which the SSC fails to perform its safety function;

- Consideration of functions such as emergency response, control rooms, etc.;

- Limited deformations of design equipment and subsystems in order to maintain safety function.

Potential damage to and/or failure of IROFS as the result of ground movement and/or the seismic response of adjacent or interior IROFS should also be considered in the ISA and ISA summary accident sequence evaluations. Damage or failures that also should be considered include the following:

- Seismic-induced failure of a facility component that is not an IROFS but that can fall and damage an IROFS (for example, a heavy load drop from a crane onto a container).

- Displacement of adjacent IROFS during a seismic event causing them to pound together.

- Displacement of adjacent components resulting in failure of connecting pipes or cables which may cause flooding, fires, and/or releases of radiological or chemical materials.

Seismic event evaluations should also consider potential multiple failures of IROFS (i.e., multiple failures of tanks). For a consequence to affect the public or external site workers, licensed material or hazardous chemicals that could affect the safety of licensed material must be released through at least one, and often two, confinement barriers, such as the following:

- Storage containers, glove boxes, tanks, or handling devices;

- Ventilation system dynamic confinement and filtration;

- Building structural shell.

By using risk reduction factors calculated for a facility and its specific components and/or estimating the degree of failure by comparison with the observed behavior of similarly constructed buildings during severe earthquakes, licensees can postulate reasonable scenarios. These scenarios may not release all the material at risk or present an unimpeded leak path to receptors. For example, some facilities might be able to show that, even in the case of an earthquake that is highly unlikely, only certain types of containers or confinement systems are likely to be breached. If the amount of material contained in such containers is variable, then that probabilistic component may be factored into the overall likelihood of the accident sequence. If employing some of these mitigating considerations in the analysis requires reliance on special containers or procedures that had not been relied upon in the existing ISA, then additional IROFS may also be needed.

Another factor to consider is the likely rate of release based on the damage sustained. For example, some facilities may lose dynamic confinement but maintain building integrity. In some processes, radiologically and/or chemically hazardous material is held inside its primary containment at subatmospheric pressure. In these cases, even though the primary containments are inside a structure designed to withstand less than a highly unlikely earthquake, the subatmospheric conditions may be sufficient to limit both facility worker and offsite doses in the event of a greater earthquake. For example, an earthquake that results in limited subatmospheric containment losses may allow adequately trained workers to evacuate and/or take mitigative actions. The buildings containing cylinders of liquid uranium hexafluoride (UF_6) at gas centrifuge facilities are designed for a highly unlikely earthquake. In addition, some buildings at one of the proposed facilities are equipped with a seismically activated interlock (an IROFS) that will shut off the building's heating, ventilation, and air conditioning system during an event, thus limiting any leakage of UF_6 to the outside.

Emergency Response and Other Considerations

The regulatory requirements in 10 CFR 70.62(c)(1) require licensees to conduct and maintain an ISA. Consistent with the regulations and guidance in NUREG-1520, licensees should establish a process to periodically re-evaluate changes to the natural phenomena data and data collection methods, modeling techniques (hazard curves), and assessment methods to ensure assumptions are still valid. If the assumptions used for the safety analysis or licensing and design basis have changed as a result of updated building codes and standards that consider NPHs as credible, the staff should assess that these changes are accommodated and can be shown acceptable by the existing safety analysis.

The effects from failures and impacts to the facility from natural phenomena events should be considered in nuclear criticality safety and fire safety assessments. Particular attention should be given to the potential for natural phenomena events to cause multiple failures as a result of common cause effects. Licensee emergency response functions should consider the necessary actions to prevent or mitigate the potential consequences of a natural phenomena event (i.e., criticality, disabled water supply, loss of electrical power, delayed off-site response). For example, licensees can establish procedures for assessing damage to facilities after severe natural phenomena events as well as emergency response procedures for re-entry to the facilities considering the effects of potential failure to alarms and instrumentation.

The operation of fuel cycle facilities inherently involves multiple significant hazards, such as: large inventories of UF_6, uranium dioxide (UO_2) and triuranium octoxide (U_3O_8) powder, fissile material that can go critical, process and byproduct chemicals such as hydrogen fluoride (HF) and nitric acid (HNO_3), and similar process hazards. Because NPH events can affect large areas of a facility, emergency response functions should consider how they would respond to events with multiple consequences and activities at the same time, which would normally require different responses.

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