Historical Perspective and U.S. Nuclear Regulation Commission Staff Evaluation Considerations

The purpose of this enclosure is to provide a historical perspective on the U.S. Nuclear Regulatory Commission (NRC) staff's evaluation of previous emergency planning (EP) related exemptions for nuclear power reactors transitioning to a decommissioning status. This enclosure provides an overview of existing EP regulations as they currently apply to a decommissioning nuclear power reactor, discuss various considerations used in the staff's evaluation, and provides the results of the staff's consultation with the Federal Emergency Management Agency (FEMA) on offsite radiological emergency preparedness (REP) considerations.

The regulations governing EP for nuclear power reactors are set forth in section 50.47, "Emergency plans," paragraphs 50.54(q), (s) and (t), and Appendix E, "Emergency Planning and Preparedness for Production and Utilization Facilities," to Part 50, "Domestic Licensing of Production and Utilization Facilities," of Title 10 of the *Code of Federal Regulations* (10 CFR), "Energy." Every nuclear power reactor licensee must establish and maintain emergency plans and preparedness in accordance with these regulations. The EP regulations for an operating nuclear power reactor include standards for both onsite and offsite[1] radiological emergency response plans. These regulations and the planning basis for EP are based upon an anticipated prompt response to a wide spectrum of events. However, for a decommissioning nuclear power reactor, the spectrum of accidents that can have significant offsite consequences is greatly reduced. At a decommissioning nuclear power reactor site, the only accident scenario that might lead to a significant radiological release is a highly unlikely, beyond design-basis event resulting in a potential spent fuel zirconium cladding fire. This event involves a postulated major loss of water inventory from the spent fuel pool (SFP), where preplanned SFP mitigation measures are unsuccessful, generating a significant heat-up of the spent fuel to the point where substantial zirconium cladding oxidation and fuel damage can occur.

The amount of decay heat present in irradiated fuel in the SFP is directly related to the amount of time that has passed after the reactor is shut down. As such, the potential for the conditions needed for a zirconium cladding fire to occur continues to decrease as a function of the time since the reactor was permanently shut down. However, current regulations do not reflect that: (1) considerably more time is available during decommissioning to respond to a postulated loss of SFP coolant event than is available for many postulated operating power reactor accidents; and (2) comprehensive SFP mitigation measures and on-shift staff remain in place following the permanent cessation of power operations.

Licensees transitioning to, or already in the decommissioning phase, usually seek to establish a level of EP commensurate with the risk of a radiological emergency at a decommissioning site, because there are no explicit regulatory provisions distinguishing EP requirements for a nuclear power reactor that has permanently ceased operation from those for an operating nuclear power reactor. Exemptions from certain EP requirements are typically requested early in the decommissioning process. The NRC reviews each request on a case-by-case basis and grants exemptions only after conducting a thorough analysis of each request. Historically, given the significant reduction in radiological risk from a decommissioning site, the NRC has approved exemptions from EP requirements based on site-specific evaluations and the objectives of the

[1] The offsite standards are addressed in FEMA regulations in 44 CFR 350.5, "Criteria for review and approval of State and local radiological emergency plans and preparedness," and are based on the standards established by the NRC in 10 CFR 50.47, "Emergency plans."

regulations. Between 1987 and 1999, the NRC issued exemptions from certain EP requirements for 10 licensees. More recently, exemptions from certain EP requirements have been granted for nine plants, which are Kewaunee Power Station; Crystal River Unit 3 Nuclear Generating Plant; San Onofre Nuclear Generating Station, Units 1, 2, and 3; Vermont Yankee Nuclear Power Station; Fort Calhoun Station, Unit 1; Oyster Creek Nuclear Generating Station; Pilgrim Nuclear Power Station; Three Mile Island Nuclear Station, Units 1 and 2; and the Duane Arnold Energy Center (Agencywide Documents Access and Management System (ADAMS) Accession Nos. ML14261A223, ML15058A906, ML15082A204, ML15180A054, ML17263B198, ML18220A980, ML19142A043, ML20244A292, and ML21097A139, respectively).

Based on the reviews of the Kewaunee Power Station and Crystal River Unit 3 Nuclear Generating Plant exemptions, the NRC staff developed and issued an Office of Nuclear Security and Incident Response (NSIR), Division of Preparedness and Response (DPR) Interim Staff Guidance (ISG) document, NSIR/DPR-ISG-02, "Emergency Planning Exemption Requests for Decommissioning Nuclear Power Plants" (ADAMS Accession No: ML14106A057), on May 11, 2015. This ISG provides guidance to NRC staff that the staff used for the subsequent technical reviews of requests for exemptions from certain EP requirements for nuclear power reactors that have been permanently shut down and defueled or are planning to transition to a decommissioning status.

The previously granted exemptions from EP regulations, identified above, reduced the requirements for decommissioning power reactors to those consistent with these standards: (1) 10 CFR 50.47(d), which states the requirements for a license authorizing fuel loading or low power testing only,[2] and (2) 10 CFR 72.32(a),[3] which establishes the information required in an emergency plan for an Independent Spent Fuel Storage Installation (ISFSI) Facility. Examples of previously granted exemptions from EP regulations for decommissioning power reactors include: setting the highest emergency plan classification level as an "Alert"; extending the timing requirements for notification of offsite authorities; requiring only onsite exercises with the opportunity for offsite response organization (ORO) participation; and maintaining arrangements only for OROs (i.e., law enforcement, fire, and medical services) that might support the licensee's response to onsite emergencies.[4] The EP exemptions also relieve the licensee from the requirement to maintain formal offsite REP plans, including the 10-mile plume exposure pathway and 50-mile ingestion pathway EP zones. However, licensees that have been granted these EP exemptions must continue to maintain an onsite emergency plan addressing the classification of an emergency, notification of emergencies to licensee personnel and offsite

[2] 10 CFR 50.47(d) states, in part, "Notwithstanding the requirements of paragraphs (a) and (b) of this section, and except as specified by this paragraph, no NRC or FEMA review, findings, or determinations concerning the state of offsite emergency preparedness or the adequacy of and capability to implement State and local or utility offsite emergency plans are required prior to issuance of an operating license authorizing only fuel loading or low power testing and training (up to 5 percent of the rated thermal power)."

[3] In the statement of considerations for the 1995 final rule for 10 CFR Part 72, "Licensing Requirements for the Independent Spent Fuel Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater Than Class C Waste," published in the Federal Register (FR) on June 22, 1995 (60 FR 32430, 32431), the Commission stated, "NUREG-1140 concluded that the postulated worst-case accident involving an ISFSI has insignificant consequences to the public health and safety. Therefore, the final requirements to be imposed on most ISFSI licensees reflect this fact, and do not mandate formal offsite components to their onsite emergency plans." The Commission also stated, "[B]ased on the potential inventory of radioactive material, potential driving forces for distributing that amount of radioactive material, and the probability of the initiation of these events, the Commission concludes that the offsite consequences of potential accidents at an ISFSI or a MRS would not warrant establishing Emergency Planning Zones" (60 FR 32435).

[4] The requirements for licensees to maintain agreements for fire-fighting and local law enforcement services exist outside of EP requirements (i.e., the requirement for licensees to maintain a fire protection plan in 10 CFR 50.48, "Fire protection" and physical security requirements in 10 CFR Part 73, "Physical Protection of Plants and Materials").

authorities, and coordination with designated offsite government officials following an event declaration.

In evaluating EP exemptions requested by Holtec Decommissioning International, LLC (the licensee), specifically in relation to relieving the licensee from the requirement to maintain formal offsite REP plans, the NRC staff considered the conclusions from recent SFP studies completed since the publication of NUREG-1738, "Technical Study of Spent Fuel Pool Accident Risk at Decommissioning Nuclear Power Plants" (ADAMS Accession No: ML010430066), which served as the technical basis for SECY-01-0100, "Policy Issues Related to Safeguards, Insurance, and Emergency Preparedness Regulations at Decommissioning Nuclear Power Plants Storing Fuel in Spent Fuel Pools" (ADAMS Accession No: ML011450420). In addition, the staff considered enhancements put into place as a result of the events of September 11, 2001, and the March 11, 2011, accident at the Fukushima Dai-ichi site. The studies, described in more detail below, support staff positions that only a highly unlikely beyond-design-basis event (e.g., extreme earthquake or large aircraft impact) could potentially cause sufficient structural damage to the SFP structure to result in a rapid SFP water draindown and potential zirconium cladding fire. In addition, there would be a significant amount of time between the initiating event (i.e., the event that causes the SFP water level to drop) and the possible onset of conditions that could result in a zirconium cladding fire. This time provides a substantial opportunity for event mitigation. Licensees are required to maintain effective strategies, sufficient resources, and adequately trained personnel to mitigate such an event. If State or local governmental officials determine that offsite protective actions are warranted, then sufficient time and capability would also be available for OROs to implement these measures using a comprehensive emergency management plan (CEMP) or "all-hazards" approach.[5]

SFP Study Considerations

Following permanent removal of spent fuel from the reactor vessel, the principal radiological risks are associated with the storage of spent fuel onsite. Generally, a few months after the reactor has been permanently shut down, there are no possible design-basis events that could result in a radiological release exceeding the U.S. Environmental Protection Agency (EPA) early phase protective action guides (PAGs) limit of one roentgen equivalent man at the exclusion area boundary. The only potential accident that might lead to a significant radiological release at a decommissioning reactor is a zirconium cladding fire. The zirconium cladding fire scenario is a postulated, but highly unlikely, beyond-design-basis accident scenario that involves a major loss of water inventory from the SFP, resulting in a significant heat-up of the spent fuel, and culminating in substantial zirconium cladding oxidation and fuel damage. The significance of the spent fuel heat-up scenario that might result in a zirconium cladding fire depends on the decay heat of the irradiated fuel stored in the SFP. The amount of decay heat in the spent fuel is directly associated with the amount of time since the reactor permanently ceased operations. Therefore, the probability of a zirconium cladding fire scenario continues to decrease as a function of the time that the decommissioning reactor has been permanently shut down.

The NRC staff assessed the risk of an SFP accident at decommissioning nuclear power plants in the late 1990s to support the development of a risk-informed technical basis for the review of exemption requests and a regulatory framework for integrated rulemaking. The staff's

[5] A CEMP or "all-hazards" approach in this context, also referred to as an emergency operations plan, is addressed in FEMA's Comprehensive Preparedness Guide (CPG) 101, "Developing and Maintaining Emergency Operations Plans," Version 2.0, dated November 2010. https://www.fema.gov/sites/default/files/2020-07/developing-maintaining-emergency-operations-plans.pdf

assessment, published in NUREG-1738, conservatively assumed that if the water level in the SFP did drop below the top of the spent fuel, a zirconium cladding fire involving all the spent fuel in the SFP would occur, and thereby bounded those conditions associated with inadequate air cooling of the fuel (including partial draindown scenarios) and fire propagation. The study used simplified and sometimes bounding assumptions and models to characterize the likelihood and consequences of beyond-design-basis SFP accidents. Even with this conservative assumption, the study found the risk of a zirconium cladding fire in the SFP to be low and well within the Commission's safety goals. The amount of time available after the fuel is completely uncovered, but before a zirconium cladding fire, depends on various factors, including decay heat rate, fuel burnup, fuel storage configuration, building ventilation rates and air flow paths, and fuel cladding oxidation rates. Although NUREG-1738 did not completely rule out the possibility of a zirconium cladding fire, it did demonstrate that storage of spent fuel in a high-density configuration in SFPs is safe, and that the risk of accidental release of a significant amount of radioactive material to the environment is low.

After the events of September 11, 2001, Sandia National Laboratories (SNL) conducted studies (collectively referred to as the "Sandia studies")[6] that considered spent fuel loading patterns and other aspects of an SFP at a pressurized-water reactor and at a boiling water reactor, including the role that the circulation of air plays in the cooling of spent fuel. The Sandia studies indicated that there is a significant amount of time between the initiating event and the spent fuel assemblies becoming partially or completely uncovered. In addition, the Sandia studies indicated that for those hypothetical conditions where air cooling may not be effective in preventing a zirconium cladding fire, there is a significant amount of time between the spent fuel becoming uncovered and the possible onset of such a zirconium cladding fire, thereby providing a substantial opportunity for event mitigation. The Sandia studies, which account for relevant heat transfer and fluid flow mechanisms, also indicated that the air cooling of spent fuel could be sufficient to prevent SFP zirconium fires at a point much earlier following fuel offload from the reactor than previously considered (e.g., in NUREG-1738).

In NUREG-2161, "Consequence Study of a Beyond-Design-Basis Earthquake Affecting the Spent Fuel Pool for a U.S. Mark I Boiling Water Reactor," dated September 2014 (ADAMS Accession No: ML14255A365), the NRC evaluated the potential benefits of strategies required in 10 CFR 50.54(hh)(2), "Conditions of licenses," (now 10 CFR 50.155(b)(2)), "Mitigation of beyond-design-basis events.").[7] The study results for the analyzed severe earthquake at the referenced plant are consistent with conclusions in past studies that SFPs are robust structures and likely to withstand severe earthquakes without leaking. The study showed the likelihood of a radiological release from the spent fuel resulting from a severe earthquake at the referenced plant to be about one time in 10 million years or lower. If a radiological release were to occur, this study shows that the individual cancer fatality risk for a member of the public is several orders of magnitude lower than the Commission's Quantitative Health Objective of two times in 1 million years ($2x10^{-6}$/year). As explained in NUREG-2161, successful implementation of mitigation strategies significantly reduces the likelihood of a release from the SFP in the event of a loss of cooling water. Additionally, the NRC found that the placement of spent fuel in a dispersed configuration in the SFP, such as the 1 x 4 pattern, more effectively used the heat capacity of the stored fuel and available cooling mechanisms to extend the heat-up time and reduce the likelihood of a release from a completely drained SFP.

[6] A redacted summary of the Sandia studies is publicly available (ADAMS Accession No: ML120970086).
[7] Mitigation of Beyond-Design-Basis Events; Final rule (84 FR 39684; August 9, 2019).

In 2013, the NRC documented a regulatory analysis of expediting the transfer of spent fuel assemblies in COMSECY-13-0030, “Staff Evaluation and Recommendation for Japan Lessons-Learned Tier 3 Issue on Expedited Transfer of Spent Fuel” (ADAMS Accession No: ML13329A918). The NRC staff concluded that SFPs are robust structures with large safety margins and recommended to the Commission that possible regulatory actions to require the expedited transfer of spent fuel from SFPs to dry cask storage were not warranted. The Commission subsequently approved the staff’s recommendation in the staff requirements memorandum to COMSECY-13-0030 (ADAMS Accession No: ML14143A360).

To inform the current integrated decommissioning rulemaking effort, the NRC staff conducted an applied research study, as documented in “Transmittal of Reports to Inform Decommissioning Plant Rulemaking for User Need Request NSIR-2015-001,” dated May 31, 2016 (ADAMS Accession No: ML16110A416), and concluded that:

- the representative plant staff can reliably implement mitigation strategies to timely mitigate cask-drop events and prevent spent fuel heat-up damage;
- only the events causing a rapid SFP water draindown (e.g., extreme earthquake or large aircraft impact) would challenge the successful mitigation of fuel heat-up; and
- even in the event of a highly unlikely beyond-design-basis accident leading to a rapid draindown of the SFP and subsequent zirconium cladding fire, there may be an additional time margin on the order of several hours beyond the 10-hour heat-up time during which protective actions can be taken to protect the public before the dose levels associated with EPA early phase PAGs would be exceeded offsite.

In addition, for the hypothetical event sequence considered in the highly unlikely beyond-design-basis accident leading to a rapid draindown of the SFP and subsequent zirconium cladding fire, acute fatal effects offsite appear to be unlikely from either source term evaluated, provided that individuals can be relocated within a reasonable time after plume arrival, which in most cases was longer than 24 hours.

As previously stated, these studies (NUREG-1738, the Sandia studies, NUREG-2161, COMSECY-13-0030, and studies supporting the decommissioning rulemaking effort) support the NRC staff positions that:

- there would be sufficient time between the initiating event and the possible onset of conditions that could result in a zirconium cladding fire, which would provide a substantial opportunity for successful mitigation measures; and
- only a highly unlikely, beyond-design-basis event (e.g., extreme earthquake or large aircraft impact) would cause sufficient SFP structural damage to uncover the fuel and potentially support development of a zirconium cladding fire and, even in such cases, the fuel may be air coolable following a complete draindown.

As such, the NRC staff believes that for all but the most unlikely events, any offsite protective actions would be taken by governmental officials as a precautionary measure. In the highly unlikely event of a beyond-design-basis accident resulting in a loss of the SFP water inventory, there would be time to initiate appropriate SFP mitigating actions. If State or local governmental officials determine that offsite protective actions are warranted, then sufficient time and capability would be available for OROs to implement these measures using a CEMP approach.

Spent Fuel Pool Hostile Action-Based Event Considerations

Licensees develop strategies to protect against the NRC design-basis threat (DBT)[8] for radiological sabotage and are required to maintain these strategies under the provisions of 10 CFR 73.55(b), "Requirements for physical protection of licensed activities in nuclear power reactors against radiological sabotage – General performance object and requirements," until the termination of their 10 CFR Part 50 (or 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants,") license. In addition, other Federal agencies such as the Federal Aviation Administration, the Federal Bureau of Investigation, and the Department of Homeland Security have taken aggressive steps to prevent terrorist attacks in the United States. Taken as a whole, these systems, personnel, and procedures provide reasonable assurance that public health and safety, the environment, and the common defense and security will be adequately protected (73 FR 46204, 46207; August 8, 2008).

The NRC's regulatory activities and studies reaffirmed the safety and security of spent fuel stored in pools and showed that SFPs are effectively designed to prevent accidents and minimize damage from malevolent attacks. In the wake of the terrorist attacks of September 11, 2001, the NRC took several actions to further reduce the possibility of a zirconium cladding fire in an SFP. The NRC issued Order EA-02-026, "Order for Interim Safeguards and Security Compensatory Measures," dated February 25, 2002 (ADAMS Accession No: ML020510635), requiring licensees to immediately implement additional security measures, including increased patrols, augmented security forces and capabilities, and more restrictive site-access controls to, among other things, reduce the likelihood of an SFP accident resulting from a terrorist-initiated event. Through the NRC's issuance of the "Power Reactor Security Requirements" final rule on March 27, 2009 (74 FR 13925), the agency codified generically applicable security requirements that had been previously issued by orders. Subsequently, by letter dated November 28, 2011 (ADAMS Accession No: ML111220447), the NRC partially rescinded Order EA-02-026. The requirements of Order EA-02-026 that were addressed by Interim Compensatory Measure B.1.a involved operator training for specific security-initiated events that were not covered by proposed or existing regulations and remained in effect after the NRC rescinded part of the Order in November 2011.

Spent Fuel Pool Mitigative Action Considerations

The NRC's Order EA-02-026 also established new requirements for licensees to have mitigating strategies for the potential loss of SFP water inventory and for large fires or explosions at nuclear power plants. In response, the Nuclear Energy Institute (NEI) provided detailed guidance in NEI 06-12, "B.5.b Phase 2 & 3 Submittal Guideline," Revision 2, dated December 2006 (ADAMS Accession No: ML070090060), which the NRC endorsed on December 22, 2006 (ADAMS Accession No: ML063560235[9]). The NRC found the NEI guidance to be an effective means for mitigating the potential loss of large areas of the plant due to fires or explosions. In addition, these strategies enhanced the ability to cool the spent fuel and the potential to recover SFP water level as well as cooling prior to a potential SFP zirconium cladding fire, which further reduced the probability of a radiological release from an SFP zirconium cladding fire initiation.

[8] The DBT represents the largest threat against which a private sector facility can be reasonably expected to defend, with high assurance (72 FR 12705; March 19, 2007).
[9] Not publicly available because it contains security-related information.

The 2009 Power Reactor Security Requirements final rule added the requirement for licensees to implement mitigating measures to maintain or restore SFP cooling capability in the event of loss of large areas of the plant due to fires or explosions, which further decreases the probability of a zirconium cladding fire in an SFP. Under 10 CFR 50.155(b)(2), nuclear power reactor licensees are required to implement strategies such as those provided in NEI 06-12.[10]

Further, other organizations, such as SNL, as discussed previously in this enclosure under "Spent Fuel Pool Study Considerations," have confirmed the effectiveness of the additional mitigation strategies to maintain spent fuel cooling in the event that the pool is drained, and its initial water inventory is reduced or lost entirely.

In response to the accident at the Fukushima Dai-ichi site, the NRC implemented regulatory actions to further enhance reactor and SFP safety. On March 12, 2012, the NRC issued Order EA-12-049, "Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events" (ADAMS Accession No: ML12054A735), which requires licensees to develop, implement, and maintain guidance and strategies to maintain or restore SFP cooling capabilities, independent of normal alternating current power systems, following a beyond-design-basis external event. In addition, on March 12, 2012, the NRC issued Order EA-12-051, "Order Modifying Licenses with Regard to Reliable Spent Fuel Pool Instrumentation" (ADAMS Accession No: ML12054A679), which requires that licensees install reliable means of remotely monitoring wide-range SFP levels to support effective prioritization of event mitigation and recovery actions in the event of a beyond-design-basis external event. Although the primary purpose of the order was to ensure that operators were not distracted by uncertainties related to SFP conditions during the accident response, the improved monitoring capabilities will help in the diagnosis and response to potential losses of SFP integrity. These requirements ensure that a more reliable and robust mitigation capability is in place to address degrading conditions in SFPs resulting from certain significant but unlikely events. Through the NRC's issuance of the "Mitigation of Beyond-Design-Basis Events" final rule on August 9, 2019, the agency codified the generally applicable requirements in Orders EA-12-049 and -051.

Spent Fuel Pool Offsite Radiological Emergency Preparedness Considerations

In a letter dated August 12, 2022 (ADAMS Accession No: ML22228A227), FEMA provided the following statements for inclusion based on its review of a draft of this SECY paper.

> FEMA defers to Holtec Decommissioning International, LLC (HDI) and the NRC, regarding the technical analysis and evaluation respectively, in support of this exemption request from certain emergency planning requirements. FEMA recognizes the NRC's role to analyze the possibility of incidents that could result in offsite dose impacts. However, FEMA acknowledges that individual states and local governments have the primary authority and responsibility to protect their citizens and respond to disasters and emergencies and should be engaged in every phase of the decommissioning process. The exemption, if issued, could create a transitional environment for off-site emergency planners in how they consider radiological hazards. FEMA will continue to support offsite organizations

[10] The guidance in NEI 06-12 specifies that portable, power-independent pumping capabilities must be able to provide at least 500 gallons per minute (gpm) of bulk water makeup to the SFP, and at least 200 gpm of water spray to the SFP. Recognizing that the SFP is more susceptible to a release when the spent fuel is in a non-dispersed configuration, the guidance also specifies that the portable equipment is to be capable of being deployed within 2 hours for a non-dispersed configuration.

as they adjust their plans, capabilities, and resources to the changing radiological threat. Among the resources available to support FEMA stakeholders during the transition process include, but are not limited to, the National Preparedness System guidance materials, the Federal Radiological Preparedness Coordinating Committee, and assistance from FEMA Headquarters and Regional Staff.
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