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NUCLEAR REGULATORY COMMISSION

10 CFR Part 50

[Docket Nos. PRM-50-108; NRC-2014-0171]

Fuel-Cladding Issues in Postulated Spent Fuel Pool Accidents

AGENCY: Nuclear Regulatory Commission.

ACTION: Petition for rulemaking; denial.

SUMMARY: The U.S. Nuclear Regulatory Commission (NRC) is denying a petition for rulemaking (PRM), PRM-50-108, submitted by Mr. Mark Edward Leyse (the petitioner). The petitioner requested that the NRC require power reactor licensees to perform evaluations to determine the potential consequences of various postulated spent fuel pool (SFP) accident scenarios. The evaluations would be required to be submitted to the NRC for informational purposes. The NRC is denying the petition because the NRC does not believe the information is needed for effective NRC regulatory decisionmaking with respect to SFPs or for public safety, environmental protection, or common defense and security.

DATES: The docket for the petition for rulemaking, PRM-50-108, is closed on **[INSERT DATE OF PUBLICATION IN THE *FEDERAL REGISTER*]**.

ADDRESSES: Please refer to Docket ID NRC-2014-0171 when contacting the NRC about the availability of information for this petition. You may obtain publicly-available information related to this action by any of the following methods:

- **Federal Rulemaking Web Site:** Go to http://www.regulations.gov and search for Docket ID NRC-2014-0171. Address questions about NRC dockets to Carol Gallagher; telephone: 301-415-3463; e-mail: Carol.Gallagher@nrc.gov. For technical questions, contact the individual listed in the FOR FURTHER INFORMATION CONTACT section of this document.

- **The NRC's Agencywide Documents Access and Management System (ADAMS):** You may obtain publicly-available documents online in the ADAMS Public Document collection at http://www.nrc.gov/reading-rm/adams.html. To begin the search, select "ADAMS Public Documents" and then select "Begin Web-Based ADAMS Search." For problems with ADAMS, please contact the NRC's Public Document Room (PDR) reference staff at 1-800-397-4209, 301-415-4737, or by e-mail to pdr.resource@nrc.gov. The ADAMS accession number for each document referenced (if it is available in ADAMS) is provided the first time that it is mentioned in the SUPPLEMENTARY INFORMATION section. For the convenience of the reader, instructions about obtaining materials referenced in this document are provided in Section IV, "Availability of Documents," of this document.

- **The NRC's PDR:** You may examine and purchase copies of public documents at the NRC's PDR, O1-F21, One White Flint North, 11555 Rockville Pike, Rockville, Maryland 20852.

FOR FURTHER INFORMATION CONTACT: Daniel Doyle, Office of Nuclear Reactor Regulation; U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001; telephone: 301-415-3748; e-mail: Daniel.Doyle@nrc.gov.

SUPPLEMENTARY INFORMATION:

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IV. Availability of Documents.

I. The Petition.

Section 2.802 of Title 10 of the *Code of Federal Regulations* (10 CFR), “Petition for rulemaking,” provides an opportunity for any interested person to petition the Commission to issue, amend, or rescind any regulation. The NRC received a petition for rulemaking dated June 19, 2014, from Mr. Mark Edward Leyse and assigned it Docket No. PRM-50-108 (ADAMS Accession No. ML14195A388). The NRC published a notice of docketing in the *Federal Register* (FR) on October 7, 2014 (79 FR 60383). The NRC did not request public comment on the petition because sufficient information was available for the NRC staff to form a technical opinion regarding the merits of the petition.

The petitioner requested that the NRC develop new regulations requiring that: (1) SFP accident evaluation models use data from multi-rod bundle (assembly) severe accident experiments for calculating the rates of energy release, hydrogen generation, and fuel cladding oxidation from the zirconium-steam reaction; (2) SFP accident evaluation models use data from multi-rod bundle (assembly) severe accident experiments conducted with pre-oxidized fuel cladding for calculating the rates of energy release (from both fuel cladding oxidation and fuel cladding nitriding), fuel cladding oxidation, and fuel cladding nitriding from the zirconium-air reaction; (3) SFP accident evaluation models be required to conservatively model nitrogen-induced breakaway oxidation behavior; and (4) licensees be required to use conservative SFP accident evaluation models to perform annual SFP safety evaluations of: postulated complete loss-of-coolant accident (LOCA) scenarios, postulated partial LOCA scenarios, and postulated boil-off accident scenarios.

The petitioner referenced recent NRC post-Fukushima MELCOR simulations of boiling-water reactor Mark I SFP accident/fire scenarios. The petitioner stated that the conclusions from the NRC’s MELCOR simulations are non-conservative and misleading because their conclusions underestimate the probabilities of large radiological releases from

SFP accidents.

The petitioner asserted that in actual SFP fires, there would be quicker fuel-cladding temperature escalations, releasing more heat, and quicker axial and radial propagation of zirconium (Zr) fires than MELCOR ~~indicates~~simulations predict. The petitioner stated that the NRC's philosophy of defense-in-depth requires the application of conservative models, and, therefore, it is necessary to improve the performance of MELCOR and any other computer safety models that are intended to accurately simulate SFP accident/fire scenarios.

The petitioner ~~claimed~~ stated that the new regulations would help improve public and plant-worker safety. The petitioner asserted that the first three requested regulations, regarding zirconium fuel cladding oxidation and nitriding, as well as nitrogen-induced breakaway oxidation behavior, are intended to improve the performance of computer safety models that simulate postulated SFP accident/fire scenarios. The petitioner stated that the fourth requested regulation would require that licensees use conservative SFP accident evaluation models to perform annual SFP safety evaluations of postulated complete LOCA scenarios, postulated partial LOCA scenarios, and postulated boil-off accident scenarios. The petitioner stated that the purpose of these evaluations would be to keep the NRC informed of the potential consequences of postulated SFP accident/fire scenarios as fuel assembles were added, removed, or reconfigured in licensees' SFPs. The petitioner stated that the requested regulations are needed because the probability of the type of events that could lead to SFP accidents is relatively high.

The NRC staff reviewed the petition and, based on its understanding of the overall argument in the petition, identified and evaluated the following three issues:

- Issue 1: The requested regulations pertaining to SFP accident evaluation models are needed because the probability of the type of events that could lead to SFP accidents is relatively high.

- Issue 2: Annual licensee SFP safety evaluations and submission of results to the NRC is necessary so that the NRC is aware of potential consequences of postulated SFP accident/fire scenarios as fuel assemblies are added, removed, or reconfigured in licensees' SFPs.

- Issue 3: MELCOR is not currently sufficient to provide a conservative evaluation of postulated SFP accident/fire scenarios for use in the PRM-proposed annual SFP evaluations.

Detailed NRC responses to the three issues are provided in Section II, "Reasons for Denial," of this document.

II. Reasons for Denial.

The NRC is denying the petition because the petitioner failed to present any significant information or arguments that would warrant the requested regulations. The first three requested regulations would establish requirements for how the detailed annual evaluations that would be required by ~~in~~ the fourth requested regulation ~~should~~ would be performed. It is not necessary to require detailed annual evaluations of the progression of SFP severe accidents because the risk of an SFP severe accident is low. The NRC defines risk as the product of the probability and the consequences of an accident. The requested annual evaluations are not needed for regulatory decisionmaking, and the evaluations would not prevent or mitigate an SFP accident. The petitioner described multiple ways that an extended loss of offsite electrical power could occur and how this could lead to an SFP fire. In order for an SFP fire to occur, all SFP systems, backup systems, and operator actions ~~would have to fail~~ that are intended to prevent the spent fuel in the pool from being uncovered would have to fail. The NRC does not agree that more detailed accident evaluation models need to be developed for this purpose, as requested by the petitioner, because the requested annual evaluations are not needed for regulatory decisionmaking. The NRC recognizes that the consequences of an SFP fire could be large and that is why there are numerous requirements in place to prevent a situation where the spent fuel is uncovered.

This section provides detailed NRC responses to the three issues identified in the petition.

Issue 1: The requested regulations pertaining to SFP accident evaluation models are needed because the probability of the type of events that could lead to SFP accidents is relatively high.

The petitioner ~~claimed~~ stated that the requested regulations pertaining to SFP accident evaluation models are needed because the probability of the type of events that could lead to SFP accidents is relatively high. The petitioner stated that an SFP accident could happen as a result of a leak (rapid drain down) or boil-off scenario. Furthermore, the petitioner notes that in the event of a long-term station blackout, emergency diesel generators could run out of fuel and SFP cooling would be lost, resulting in a boil-off of SFP water inventory and a subsequent release of radioactive materials from the spent fuel. The petitioner also provided several examples of events that could lead to a long-term station blackout and, ultimately, an SFP accident, such as a strong geomagnetic disturbance, a nuclear device detonated in the earth's atmosphere, a pandemic, or a cyber or physical attack.

NRC Response.

Spent nuclear fuel offloaded from a reactor is initially stored in an SFP. The SFPs at all nuclear plants in the United States are ~~extremely~~ robust structures constructed with thick, reinforced, concrete walls and welded stainless-steel liners. They are designed to safely contain the spent fuel discharged from a nuclear reactor under a variety of normal, off-normal, and hypothetical accident conditions (e.g., loss of electrical power, loss of cooling, fuel or cask drop incidents, floods, earthquakes, or extreme weather events). Racks fitted in the SFPs store the fuel assemblies in a controlled configuration so that the fuel is maintained in a sub-critical and coolable geometry. Redundant monitoring, cooling, and water makeup systems are provided. The spent fuel assemblies are typically covered by at least 25-feet of water, which provides passive cooling as well as radiation shielding ~~as a result of the significant volume of water above the spent fuel~~. Penetrations to pools are limited to prevent inadvertent drainage, and the penetrations are generally located well above spent fuel storage elevations to prevent uncovering of fuel from drainage. ~~As spent fuel cools, older fuel is sometimes removed from a~~

~~plant's SFP for on-site dry cask storage, depending on the space available in the SFP. Fuel removal is performed using specially designed transfer and storage casks that are licensed by the NRC. These dry storage casks are shielded to limit radiation exposure. They are monitored and routinely inspected for integrity, and they are protected by security measures.~~

Studies conducted over the last four decades have consistently shown ~~that~~ the ~~probability~~ risk of an accident causing a zirconium fire in an SFP to be low~~er than that for severe reactor accidents~~. The risk of an SFP accident was examined in the 1980s as Generic Issue 82, "Beyond Design Basis Accidents in Spent Fuel Pools,"~~,~~ in light of increased use of high-density storage racks and laboratory studies that indicated the possibility of zirconium fire propagation between assemblies in an air-cooled environment (Section 3 of NUREG-0933, "Resolution of Generic Safety Issues," http://nureg.nrc.gov/sr0933/). The risk assessment and cost-benefit analyses developed through this effort, Section 6.2 of NUREG-1353, "Regulatory Analysis for the Resolution of Generic Issue 82, Beyond Design Basis Accidents in Spent Fuel Pools" (ADAMS Accession No. ML082330232), concluded that the risk of a severe accident in the SFP was low and appeared to meet the objectives of the Commission's Safety Goal Policy Statement public health objectives (51 FR 30028; August 21, 1986~~; 51 FR 30028~~) and that no new regulatory requirements were warranted.

The risk of an SFP accident was re-assessed in the late 1990s to support a risk-informed rulemaking for permanently shutdown, or decommissioned, nuclear power plants in the United States. The study, NUREG-1738, "Technical Study of Spent Fuel Pool Accident Risk at Decommissioning Nuclear Power Plants" (ADAMS Accession No. ML010430066), conservatively assumed that if the water level in the SFP dropped below the top of the spent fuel, an SFP zirconium fire involving all of the spent fuel would occur, and thereby bounded those conditions associated with air cooling of the fuel (including partial-drain down scenarios) and fire propagation. Even ~~when all events leading to the spent fuel assemblies becoming partially or completely uncovered were assumed to result in a SFP zirconium fire~~ with this conservative assumption, the study found the risk of an SFP fire to be low and well within the Commission's Safety Goals.

~~In light of the changes in storage configuration of the SFP (increased to high density racks), inadvertent partial draindown events, as well as monumental events such as the September 11, 2001, terrorist attacks and the 2011 accident at the Fukushima Dai-ichi nuclear power plant, the NRC continues to examine the issue of SFP safety.~~ Additional mechanisms to mitigate the potential loss of SFP water inventory were implemented following the terrorist attacks of September 11, 2001, which have enhanced spent fuel coolability and the potential to recover SFP water level and cooling prior to a potential SFP zirconium fire (73 FR 76204; August 8, 2008). Based on the implementation of these additional strategies, the probability ~~of~~ and, accordingly, the risk, of an SFP zirconium fire initiation has decreased and is expected to be less than previously analyzed in NUREG-1738 and previous studies.

~~Recently, the NRC conducted a regulatory analysis 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), which considered a broad history of the NRC's oversight of spent fuel storage, SFP operating experience (domestic and international), as well as information compiled 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" (ADAMS Accession No. ML14255A365). The COMSECY-13-0030 concluded that SFPs are very robust structures with large safety margins and proposed regulatory actions to further enhance safety were not warranted. The Commission subsequently concluded that no regulatory action needed to be pursued in the Staff Requirements Memorandum to COMSECY-13-0030 (ADAMS Accession No. ML14143A360).~~

~~Additional mechanisms to mitigate the potential loss of SFP water inventory were implemented following the terrorist attacks of September 11, 2001, which have enhanced spent fuel coolability and the potential to recover SFP water level and cooling prior to a potential SFP zirconium fire (73 FR 76204; August 8, 2008). Based on the implementation of these additional~~

~~strategies, the probability of and, accordingly, the risk of a SFP zirconium fire initiation has decreased and is expected to be less than previously analyzed in NUREG-1738 and previous studies.~~

Following the 2011 accident at Fukushima Dai-ichi, the NRC ~~has taken~~took extensive actions to ensure that portable equipment is available to mitigate a loss of cooling water in the SFP. 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). This order required licensees to develop, implement, and maintain guidance and strategies to maintain or restore core cooling, containment, and SFP cooling capabilities following a beyond-design-basis external event. The NRC endorsed the Nuclear Energy Institute (NEI) guidance to meet the requirements of this order.[1] That guidance establishes additional mechanisms for mitigating a loss of SFP cooling water beyond the requirements in 10 CFR 50.54(hh)(2), such as installing a remote connection for SFP makeup water that can be accessed away from the SFP refueling floor.

~~Recently~~Also, in 2014, the NRC ~~conducted~~documented a regulatory analysis 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), which considered a broad history of the NRC's oversight of spent fuel storage, SFP operating experience (domestic and international), as well as information compiled 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" (ADAMS Accession No. ML14255A365). ~~The~~In COMSECY-13-0030, the NRC staff concluded that SFPs are ~~very~~ robust structures with large safety margins and recommended to the Commission that assessments of possible~~proposed~~ regulatory actions to require the expedited transfer of spent fuel from SFPs to dry cask storage~~further enhance safety~~ were not warranted. The Commission subsequently ~~concluded~~

[1] See NEI 12-06, "Diverse and Flexible Coping Strategies (FLEX) Implementation Guide," dated August 2012 (ADAMS Accession No. ML12242A378), and JLD-ISG-2012-01, "Compliance with Order EA-12-049, Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events," dated August 2012 (ADAMS Accession No. ML12229A174).

~~that no regulatory action needed to be pursued~~approved the staff's recommendation in the Staff Requirements Memorandum to COMSECY-13-0030 (ADAMS Accession No. ML14143A360).

As supported by numerous evaluations referenced in this notice, the NRC has determined that the risk of an SFP severe accident is low. While the risk of a severe accident in an SFP is not negligible, the NRC believes that the risk is low because of the conservative design of SFPs; operational criteria to control spent fuel movement, monitor pertinent parameters, and maintain cooling capability; mitigation measures in place if there is loss of cooling capability or water; and emergency preparedness measures to protect the public. The information proposed to be provided to the NRC is not needed for the effectiveness of NRC's approach for ensuring SFP safety. The NRC notes that the issue of long-term cooling of SFPs is the subject of PRM-50-96, which was accepted for consideration in the rulemaking process (77 FR 74788; December 18, 2012~~; 77 FR 74788~~) and is being addressed by the NRC's rulemaking regarding mitigation of beyond design-basis events (RIN 3150-AJ49; NRC-2014-0240).

Issue 2: Annual licensee SFP safety evaluations and submission of results to the NRC is necessary so that the NRC is aware of potential consequences of postulated SFP accident/fire scenarios as fuel assemblies are added, removed, or reconfigured in licensees' SFPs.

The petitioner stated that the purpose of the proposed requirement is to keep the NRC informed of the potential consequences of postulated SFP accident/fire scenarios as fuel assemblies are added, removed, or reconfigured in licensees' SFPs.

NRC Response.

The NRC does not agree that this is necessary because the NRC already evaluates SFP systems and structures during initial licensing and ~~for~~ license amendment reviews.~~requests~~ In addition, baseline NRC inspections provide~~and provides~~ ongoing oversight to ensure adequate protection. There are not sufficient benefits that would justify the new requirement proposed in the petition for SFP accident evaluations. The proposed new requirement for licensees to perform SFP evaluations would not prevent or mitigate an SFP accident or provide information that is necessary for regulatory decisionmaking. The annual licensee SFP safety evaluations and ~~its~~ their results proposed to be provided to the NRC ~~is~~ are not needed for the effectiveness of the NRC's approach ~~for~~ to ensuring SFP safety.

The NRC issues licenses after reviewing and approving the design and licensing bases contained in the plant's ~~final~~ safety analysis report. Licensees are required to operate the plant, including performing operations and surveillances related to spent fuel, in accordance with technical specifications and established practices and procedures for that plant. Any licensee changes to design, operational or surveillance practices, or approved spent fuel inventory limits or configuration changes must be evaluated using the criteria in 10 CFR 50.59, documented and retained for the duration of the operating license, and, if warranted, submitted to the NRC for prior approval.

The general design criteria (GDC) in appendix A to 10 CFR part 50 establish general expectations that licensees must meet through compliance with their plant-specific licensing basis. Several GDC apply to SFPs:

- Protecting against natural phenomena and equipment failures (GDC 2 and GDC 4);
- Preventing a substantial loss-of-coolant inventory under accident conditions (e.g., equipment failure or loss of decay and residual heat removal) (GDC 61);
- Preventing criticality of the spent fuel (GDC 62); and
- Adequately monitoring the SFP conditions for loss of decay heat removal and radiation (GDC 63).

Additionally, emergency procedures and mitigating strategies are in place to address unexpected challenges to spent fuel safety. Multiple requirements in 10 CFR part 50, as well as recent NRC orders following the Fukushima Dai-ichi accident, require redundant equipment and strategies to address loss of cooling to SFPs ~~as well as~~and protective actions for plant personnel and the public to limit exposure to radioactive materials.

The NRC provides oversight of the licensee's overall plant operations and the SFP in several ways. The NRC inspectors ensure that spent fuel is stored safely by regularly inspecting reactor and equipment vendors; inspecting the design, construction, and use of equipment; and observing "dry runs" of procedures. ~~The~~ At least two NRC resident inspectors are ~~permanently~~ ~~stationed on~~ assigned to each site to provide monitoring and inspection of routine and special activities. They are aware of, and routinely observe, SFP activities involving fuel manipulation. The NRC inspectors use inspection procedures to guide periodic inspection activities, and the results are published in publicly-available inspection reports. Special inspections may be conducted, as necessary, to evaluate root causes and licensee corrective actions if site-specific events occur. Special inspections may also evaluate generic actions taken by some or all licensees ~~to~~ as a result of an NRC order or a change in regulations.

In accordance with 10 CFR part 21, the NRC is informed of defects ~~in and failures to conform to the NRC requirements with respect to~~ and noncompliances associated with basic components, which include~~s~~ SFPs and associated drain pipes and safety-related systems, structures, and components for makeup water. This information allows the NRC to take additional regulatory action as necessary with respect to defects and ~~failures to conform~~noncompliances. The NRC is also informed of ~~the~~ events and conditions at nuclear power plants, as set forth in §§ 50.72 and 50.73. Depending upon the nature of the event or condition, ~~the~~ a nuclear power plant licensee must inform the NRC within a specified period of time of the licensee's corrective action taken or planned to be taken. These reports also facilitate effective and timely NRC regulatory oversight. Finally, information identified by a nuclear power plant applicant ~~and~~ or licensee as having a significant implication for public health and safety or common defense and security~~,~~ must be reported to the NRC within 2 days of the applicant's or licensee's identification of the information.

~~The general design criteria (GDC) in appendix A to 10 CFR part 50 establish general expectations that licensees must meet through compliance with their plant-specific licensing basis. Several GDC apply to SFPs:~~

- ~~Protecting against natural phenomena and equipment failures (GDC 2 and GDC 4);~~
- ~~Preventing a substantial loss-of-coolant inventory under accident conditions (e.g., equipment failure or loss of decay and residual heat removal) (GDC 61);~~
- ~~Preventing criticality of the spent fuel (GDC 62); and~~
- ~~Adequately monitoring the SFP conditions for loss of decay heat removal and radiation (GDC 63).~~

~~Additionally, emergency procedures and mitigating strategies are in place to address unexpected challenges to spent fuel safety. Multiple requirements in 10 CFR part 50, as well as recent NRC orders following the Fukushima Dai-ichi accident require redundant equipment and strategies to address loss of cooling to SFPs as well as protective actions for plant personnel and the public to limit exposure to radioactive materials.~~

~~It is unclear how t~~The annual evaluations requested in the petition would not provide information that is necessary for regulatory decisionmaking. The evaluations requested in the petition would postulate scenarios in which the normal cooling systems, the backup cooling methods, and the mitigation strategies have all failed to cool the stored fuel and would require the calculation of the time it would take for the stored fuel to ignite and how much of it would ignite. Due to the robustness of this equipment, the NRC views this sequence of events as extremely unlikely to occur. Since the current regulations require that the pool be designed to prevent the loss-of-coolant and subsequent uncovering of the fuel ~~uncovery~~, the information that would be obtained from the proposed requirement in the petition ~~does~~ would not impact the current design basis. Moreover, as discussed previously, the NRC's current regulatory infrastructure relevant to SFPs at nuclear power plants in the United States already contains information collection and reporting requirements that support effective NRC regulatory oversight of SFPs.

The NRC does not agree that it is necessary to impose a new requirement for licensees to perform annual evaluations of their SFPs because existing requirements and oversight are sufficient to ensure adequate protection of public health and safety.

Issue 3: MELCOR is not currently sufficient to provide a conservative evaluation of postulated SFP accident/fire scenarios.

The petitioner requested that the NRC establish requirements for SFP accident evaluation computer models to be used in the annual SFP evaluations requested in Issue 2. The petitioner ~~claimed~~ stated that there are serious flaws with MELCOR, which has been used by the NRC to model severe accident progression in SFPs, and, therefore, MELCOR is not sufficient.

NRC Response.

The NRC does not agree that it is necessary to establish requirements for SFP accident evaluation computer models because the annual SFP evaluations requested in Issue 2 are not necessary for regulatory decisionmaking. Therefore, it is not necessary for the NRC to establish requirements for how ~~the~~ such an evaluation should be conducted. Furthermore, the NRC disagrees with the petitioner's ~~claims~~ statements that MELCOR is flawed. ~~The following discussion is provided in order to address the petitioner's claims about the adequacy of MELCOR, even though this discussion does not form the basis for denial of this petition for rulemaking.~~

~~The NRC recognizes that the phenomena discussed in the petition are important to realistically evaluate the initiation and progression of SFP fires in the unlikely event of a beyond design basis accident. However, in the context of this petition, the NRC notes that the requests in the petition related to SFP severe accident evaluation models are secondary to the request for a new requirement for licensees to perform annual evaluations of SFPs. The petitioner's request to address perceived deficiencies in current severe accident models go hand-in-hand with the petitioner's request to establish a new requirement for an annual SFP evaluation because that would set the requirements for how to do the evaluation. Since the NRC has concluded that the annual SFP evaluations requested in Issue 2 are not necessary for regulatory decisionmaking, the assertions in the petition related to SFP severe accident evaluation models do not need to be addressed in detail. However, the NRC is providing the~~

~~following information about how MELCOR is used and the NRC's views on some of the phenomena discussed in the petition.~~

There are inherent uncertainties in the progression of severe accidents ~~and there are many interrelated phenomena~~. ~~Therefore, it is neither desirable nor very practical to develop a "conservative" computer safety model for severe accidents.~~ There are many interrelated phenomena that need to be properly understood ~~as,~~ otherwise~~,~~ conservatism in one area may lead to ~~some~~ overall non-conservative results. Conservatism can be meaningfully introduced into the relevant analysis after the best estimate analysis is done and uncertainties are properly taken into account.

The important question for a severe accident analysis is whether the uncertainties are appropriately considered in the analysis results. For example, Section 9 of the SFP study (NUREG-2161) is devoted to discussing the major uncertainties that can affect the radiological releases (e.g., hydrogen combustion, core concrete interaction, multi-unit or concurrent accident, or fuel loading). In addition, the regulatory analysis in COMSECY-13-0030 only relied on SFP study insights for the boiling-water reactors with Mark I and II containments, and even then, the results were conservatively biased towards higher radiological releases. For other designs, the release fractions were based on previous studies (i.e., NUREG-1738) that used bounding or conservative estimates.

The MELCOR computer code is the NRC's best estimate tool for severe accident analysis and has been validated against experimental data~~. The MELCOR computer code~~and it represents the current state of the art in severe accident analysis. 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,"~~ the NRC stated that "MELCOR has been developed through the NRC and international research performed since the accident at Three Mile Island in 1979. MELCOR is a fully integrated, engineering-level computer code and includes a broad spectrum of severe accident phenomena with capabilities to model core heatup and degradation, fission product release and transport within the primary system and containment, core relocation to the vessel lower head, and ex-vessel core concrete interaction." Furthermore, MELCOR has been benchmarked against many experiments, including separate and integral effects tests ~~testing~~ for a wide range of phenomena. Therefore, the NRC has determined that MELCOR is acceptable for its intended use.

~~Further~~Additional information about the capabilities of the MELCOR code to model SFP accidents can be found in the NRC response to stakeholder comments in Appendix E to NUREG-2161~~, "Consequence Study of a Beyond-Design-Basis Earthquake Affecting the Spent Fuel Pool for a U.S. Mark I Boiling-Water Reactor, " (ADAMS Accession No. ML14255A365)~~. The NRC also addressed questions regarding MELCOR in Appendix D to NUREG-2157, Volume 2, "Generic Environmental Impact Statement for Continued Storage of Spent Nuclear Fuel," (ADAMS Accession ~~N~~no. ML14196A107).

~~The petitioner claimed that MELCOR does not simulate the generation of heat from the chemical reaction of zirconium and nitrogen, nor does it simulate how nitrogen affects the oxidation of zirconium in air. The petitioner also claimed that MELCOR under-predicts the zirconium-steam reaction rates. These phenomena would affect the progression and severity of a SFP accident, and therefore, the petitioner claimed, MELCOR simulations underestimate the probabilities of large releases from SFP accidents because actual fires would be more severe. The petitioner pointed to a number of references published over the last few years to assert that the MELCOR computer code is inadequate.~~

~~The MELCOR computer code is the NRC's best estimate tool for severe accident analysis. It has the capability to mechanistically model the important physical phenomena given inherent uncertainties in accident progression phenomenology. The MELCOR computer code has been benchmarked against many experiments including separate and integral effects tests for a wide range of phenomena. Any new application of MELCOR requires targeted assessment of the code. The models in MELCOR have been developed over the past few decades, and are supported by experimental validation as discussed later in this section.~~

~~The MELCOR computer code is used to perform "best estimate" analysis with "uncertainty analysis" to better understand and bound phenomenological uncertainties. Best estimate in this context means that MELCOR has been validated against separate effects and integral effects experiments, so it reasonably captures the physics of the phenomena. There are inherent uncertainties in the progression of severe accidents and there are many interrelated phenomena. Therefore, it is neither desirable nor very practical to develop a "conservative" computer safety model for severe accidents. There are many interrelated phenomena that need to be properly understood as, otherwise, conservatism in one area may lead to some overall non-conservative results. Conservatism can be meaningfully introduced into the relevant analysis after the best estimate analysis is done and uncertainties are properly taken into account.~~

~~Contrary to the assertions in the petition, there is not a specific temperature peculiar to zirconium alloy cladding at which self-sustaining oxidation (i.e., "zirconium fire") occurs. A self-sustaining zirconium fire will develop if the heat-generation rate from reaction with oxidant exceeds the heat-loss rate (heat losses include both convective and radiative losses) from the reaction zone. Because both heat generation and heat losses increase with temperature, no specific temperature defines whether a self-sustaining zirconium fire will occur.~~

~~Nitriding refers to the formation of zirconium nitride (ZrN) when zirconium cladding oxidizes at high temperatures in an air environment. As an additional heat source, nitriding is only important in oxygen-starved situations (e.g., in cases where the reactor building is intact during the zirconium fire). However, in such cases the releases are likely to be limited by the decontamination afforded by the intact reactor building, due to processes such as deposition and settling within the building before the radioactive aerosols are released into the environment. At higher temperatures, the presence of any measurable amount of oxygen in the gas (steam or air) attacking the cladding is sufficient to prevent the formation of surface ZrN. Further, if ZrN does form it can be converted readily to zirconium oxide (ZrO_2) when exposed to oxygen. The heat generation from the reaction of cladding to form ZrN followed by oxidation of~~

~~the ZrN to form ZrO_2 is essentially the same as the direct reaction of Zr to form ZrO_2. This last reaction is taken into account in accident analysis codes. Detailed modeling of the current understanding of the microscopic effects of nitriding is not needed because simple empirical kinetics are sufficient to account for the effects and there is a sufficient data base of these empirical kinetics. The empirical modeling data base includes a substantial body of information on the breakaway phenomenon mentioned in the petition. The effect of nitrogen is taken into account in MELCOR in the formulation of air oxidation kinetics including the transition from pre- to post-breakaway necessary for the prediction of zirconium fire. Nitriding is most relevant when nuclear fuel is undergoing a severe accident in an air environment and oxygen-starved conditions develop because of rapid consumption of oxygen from the air. The incremental increase in clad reaction will be insignificant compared to the extensive and rapid reaction of oxygen that takes place before nitriding. Effects of localized nitriding are well within uncertainties in the high temperature air oxidation rates.~~

~~With respect to the findings in various tests cited in the petition (i.e., CORA-16 or PHEBUS B9R), these phenomena are well understood and recognized in the formulations of models. With respect to zirconium fire propagation, the axial and radial heat transfer within fuel assemblies and between groups of fuel assemblies is modeled in severe accident codes (e.g., MELCOR) needed for accident progression analysis in a SFP. The code assessment against zirconium fire experiments conducted at Sandia National Laboratory (SNL) and code-to-code comparison documented in NUREG/CR-7143, "Characterization of Thermal-Hydraulic and Ignition Phenomena in Prototypic, Full-Length Boiling Water Reactor Spent Fuel Pool Assemblies After a Postulated Complete Loss-of-Coolant Accident" (ADAMS Accession No. ML13072A056), address fire propagation phenomena.~~

~~The air oxidation kinetics models in MELCOR for zirconium-based alloys (including Zirlo and M5) are based on the research sponsored by NRC and documented in NUREG/CR-6846, "Air Oxidation Kinetics for Zr-Based Alloys" (ADAMS Accession No. ML041900069). The MELCOR computer code was used in the zirconium fire experiments (see NUREG/CR-7143)~~

~~and the predictions showed good agreement with data for the initiation and propagation of zirconium fire. The publication of experimental results in NUREG/CR-7143 (including code-to-code comparisons) as well as the SFP study (NUREG-2161) and the review by the Advisory Committee on Reactor Safeguards (ACRS) supports the adequacy of MELCOR's use for this purpose.~~

~~The recent Sandia Fuel Project by the Organisation for Economic Co-operation and Development Nuclear Energy Agency provided experimental data relevant for hydraulic and ignition phenomena of prototypic pressurized water reactor fuel assemblies and supplemented earlier results (NUREG/CR-7143) obtained for boiling water reactor assemblies. Overall, results from the code validations demonstrate that MELCOR is capable of simulating the experiments. The petitioner asserted that the SNL SFP accident experiments are unrealistic because they were conducted with clean, non-oxidized cladding, and the data from the experiments is inadequate for benchmarking MELCOR. The NRC disagrees. The SNL experimental results were appropriately applied to MELCOR. The buildup of an oxide layer happens very early prior to ignition even when there is no oxide layer present, such as with new fuel cladding. This buildup of oxide is modeled in MELCOR. The fuel assemblies in the SNL experiments went through a buildup of an oxide layer prior to ignition. The cracking of the oxide layer is responsible for the change in the oxidation kinetics and the zirconium fire. This was clear from the experiments. Had there been an existing oxide layer of more than 100 micron, it may have changed the timing of ignition somewhat but there are uncertainties in the timing because of the complex nature of breakaway phenomenon. This has a minor effect on the overall accident progression and is well within the uncertainties.~~

~~The important question for an analysis is if the uncertainties are appropriately considered in the analysis results. For example, Section 9 of the SFP study (NUREG-2161) is devoted to discussion of the major uncertainties that can affect the radiological releases (e.g., hydrogen combustion, core concrete interaction, multiunit or concurrent accident, fuel loading). In addition, the regulatory analysis in COMSECY-13-0030 only relied on SFP study insights for~~

~~the boiling-water reactors with Mark I and II containments, and even then, the results were conservatively biased towards higher radiological releases. For other designs, the release fractions were based on previous studies (i.e., NUREG-1738) that used bounding or conservative estimates. The NRC continues to believe that the use of the quantitative results from NUREG-1738 in the recent continued storage generic environmental impact statement (NUREG-2157, "Generic Environmental Impact Statement for Continued Storage of Spent Nuclear Fuel," Volumes 1 and 2 (ADAMS Accession Nos. ML14196A105 and ML14196A107)) are justified because they are based on analyses that assume that a large radiological release will occur if the water drops to 3 feet above the top of the fuel in the pool, therefore encompassing the effects of some of the phenomena mentioned by the petition.~~

~~In conclusion, it is not necessary to establish requirements for SFP accident evaluation models as requested in this petition because the NRC has concluded that the annual SFP evaluations requested in Issue 2 are not necessary for regulatory decisionmaking. The NRC has considered the most important phenomena and continues to improve the models to further reduce the uncertainties. However, the NRC wishes to emphasize that these improvement efforts do not reflect an NRC determination that the models are unacceptable for their intended use by the NRC.~~

III. Conclusion.

For the reasons described in Section II, "Reasons for Denial," of this document, the NRC is denying the petition under 10 CFR 2.803. The petitioner failed to present any information or arguments that would warrant the requested amendments. The NRC does not believe that the information that would be reported to the NRC as requested by the petitioner is necessary for effective NRC regulatory decisionmaking with respect to SFPs. The NRC continues to conclude that the current design and licensing requirements for SFPs provide adequate protection of public health and safety.

IV. Availability of Documents.

Commented [LR1]: Delete documents no longer referenced in this FRN from the table below.

The documents identified in the following table are available to interested persons as indicated. For more information on accessing ADAMS, see the ADDRESSES section of this document.

Date	Document	ADAMS Accession Number/*Federal Register* Citation
August 21, 1986	Safety Goals for the Operations of Nuclear Power Plants; Policy Statement; Republication.	51 FR 30028
April 1989	NUREG-1353, "Regulatory Analysis for the Resolution of Generic Issue 82, Beyond Design Basis Accidents in Spent Fuel Pools."	ML082330232
February 2001	NUREG-1738, "Technical Study of Spent Fuel Pool Accident Risk at Decommissioning Nuclear Power Plants."	ML010430066
~~June 2004~~	~~NUREG/CR-6846, "Air Oxidation Kinetics for Zr-Based Alloys."~~	~~ML041900069~~
March 12, 2012	EA-12-049, "Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events."	ML12054A735
August 2012	NEI 12-06, "Diverse and Flexible Coping Strategies (FLEX) Implementation Guide."	ML12242A378
August 2012	JLD-ISG-2012-01, "Compliance with Order EA-12-049, Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events."	ML12229A174
December 18, 2012	Long-Term Cooling and Unattended Water Makeup of Spent Fuel Pools.	77 FR 74788
~~March 2013~~	~~NUREG/CR-7143, "Characterization of Thermal-Hydraulic and Ignition Phenomena in Prototypic, Full-Length Boiling Water Reactor Spent Fuel Pool Assemblies After a Postulated Complete Loss-of-Coolant Accident."~~	~~ML13072A056~~
November 12, 2013	COMSECY-13-0030, "Staff Evaluation and Recommendation for Japan Lessons Learned Tier 3 Issue on Expedited Transfer of Spent Fuel."	ML13329A918

May 23, 2014	SRM-COMSECY-13-0030, “Staff Requirements – COMSECY-13-0030 – Staff Evaluation and Recommendation for Japan Lessons-Learned Tier 3 Issue on Expedited Transfer of Spent Fuel.”	ML14143A360
June 19, 2014	Incoming Petition (PRM-50-108) from Mr. Mark Edward Leyse.	ML14195A388
~~September 2014~~	~~NUREG-2157, “Generic Environmental Impact Statement for Continued Storage of Spent Nuclear Fuel,” Volume 1.~~	~~ML14196A105~~
September 2014	NUREG-2157, “Generic Environmental Impact Statement for Continued Storage of Spent Nuclear Fuel,” Volume 2.	ML14196A107
September 2014	NUREG-2161, “Consequence Study of a Beyond-Design-Basis Earthquake Affecting the Spent Fuel Pool for a U.S. Mark I Boiling-Water Reactor.”	ML14255A365
October 7, 2014	Notice of Docketing for PRM-50-108.	79 FR 60383

Dated at Rockville, Maryland, this day of , ~~2015~~2016.

For the Nuclear Regulatory Commission.

Annette L. Vietti-Cook,
Secretary of the Commission