# POLICY ISSUE
## (Notation Vote)

February 14, 2018 SECY-18-0022

FOR: The Commissioners

FROM: Victor M. McCree
Executive Director for Operations

SUBJECT: DENIAL OF PETITIONS FOR RULEMAKING ON CALCULATED MAXIMUM FUEL ELEMENT CLADDING TEMPERATURE (PRM-50-93 AND PRM-50-95; NRC-2009-0554)

PURPOSE:

To obtain Commission approval to publish the enclosed draft *Federal Register* notice (Enclosure 1) to deny two related petitions for rulemaking (PRMs), PRM-50-93 and PRM-50-95, submitted by Mark Edward Leyse (the petitioner). This paper does not address new commitments or resource implications.

SUMMARY:

The petitioner asserted that data from multirod (assembly) severe fuel damage experiments indicate that specific aspects of the U.S. Nuclear Regulatory Commission's (NRC) regulations and associated regulatory guidance on the acceptance criteria and evaluation models for emergency core cooling systems (ECCSs) are not conservative and that additional regulations are necessary to prevent core damage in the event of a loss-of-coolant accident (LOCA). The NRC staff recommends denial of these petitions because existing NRC regulations provide reasonable assurance of adequate protection of public health and safety. The petitioner did not present sufficient new information or arguments to support the requested changes. In addition, the staff disagrees with the arguments in the petitions and concludes that the requested amendments to its regulations and associated regulatory guidance are not necessary to ensure public health and safety are adequately protected.

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BACKGROUND:

On November 17, 2009, Mark Edward Leyse submitted a PRM under Subpart 2.802 of Title 10 of the *Code of Federal Regulations* (10 CFR), "Petition for Rulemaking—Requirements for Filing" (Agencywide Documents Access and Management System (ADAMS) Accession No. ML093290250). The NRC assigned docket number PRM-50-93 to this petition and published a notice of receipt and request for public comment in the *Federal Register* (FR) on January 25, 2010 (75 FR 3876).

The petitioner asserted that data from multirod (assembly) severe fuel damage experiments indicate that specific aspects of the NRC's regulations and associated regulatory guidance on ECCS acceptance criteria and evaluation models are not conservative and that additional regulations are necessary. Therefore, the petitioner requested the NRC to: (1) amend its regulations to require that the calculated maximum fuel element cladding temperature not exceed a limit based on data from cited experiments, (2) amend its regulations and associated regulatory guidance to require that the rates of energy release, hydrogen generation, and Zircaloy cladding oxidation from the metal-water reaction of zirconium with steam considered in the evaluation models used to calculate ECCS cooling performance be based on data from cited experiments, and (3) issue a new regulation that requires minimum allowable core reflood rates in the event of a LOCA.

On June 7, 2010, Mark Edward Leyse, on behalf of the New England Coalition, submitted a petition for enforcement action under 10 CFR 2.206, "Requests for Action under This Subpart" (ADAMS Accession No. ML102770018). The petitioner requested the NRC to order the Vermont Yankee Nuclear Power Station to lower its licensing basis peak cladding temperature to provide an adequate margin of safety in the event of a LOCA. The NRC staff concluded that this petition did not meet the criteria for review under 10 CFR 2.206 because it identified generic issues that could require revisions to existing NRC regulations. Therefore, the NRC decided to review it as a PRM under 10 CFR 2.802 and assigned it docket number PRM-50-95. Because PRM-50-93 and PRM-50-95 address similar issues, the NRC consolidated their review into a single activity. On October 27, 2010, the NRC published a notice of consolidation of PRM-50-93 and PRM-50-95 in the *Federal Register* (75 FR 66007) and requested public comment. The public comment period closed on November 26, 2010.

DISCUSSION:

Issues Raised in the Petitions

The staff identified three main issues in the two petitions. The sections below summarize each of these issues.

*Issue 1: Calculated Maximum Fuel Element Cladding Temperature Limit*

Under 10 CFR 50.46, "Acceptance Criteria for Emergency Core Cooling Systems for Light-Water Nuclear Power Reactors," light-water nuclear power reactors fueled with uranium oxide pellets within cylindrical Zircaloy cladding must be provided with an ECCS that must be designed so that its calculated cooling performance following postulated LOCAs conforms to the criteria in 10 CFR 50.46(b). In particular, 10 CFR 50.46(b)(1) requires that the calculated maximum fuel element cladding temperature shall not exceed 2,200 degrees Fahrenheit (F). The petitioner asserted that data from cited multirod (assembly) severe fuel damage experiments indicate that autocatalytic metal-water oxidation reactions and uncontrolled

temperature excursions involving Zircaloy cladding have occurred at temperatures below 2,200 degrees F. The petitioner provided this assertion as evidence that the 2,200-degree-F limit is not conservative, and requested the NRC to amend 10 CFR 50.46 to require that the calculated maximum fuel element cladding temperature not exceed a limit based on data from cited experiments, instead of the 2,200-degree-F limit specified in 10 CFR 50.46(b)(1).

*Issue 2: Metal-Water Reaction Rate Equations for Emergency Core Cooling System Evaluation Models*

To evaluate conformance with the criteria in 10 CFR 50.46(b), ECCS cooling performance must be calculated using an acceptable evaluation model[1] for a range of postulated LOCAs of different sizes, locations, and other properties sufficient to provide assurance that the most severe postulated LOCAs are evaluated. Under 10 CFR 50.46(a)(1), licensees or applicants may use either of two acceptable ECCS evaluation model options: (1) a best estimate or realistic evaluation model[2], or (2) a conservative evaluation model.

RG 1.157 describes models,[3] correlations,[4] data, model evaluation procedures, and methods that are generally acceptable to the staff in meeting the requirements for: (1) performing a realistic or best-estimate calculation of the ECCS cooling performance during a LOCA, (2) estimating the uncertainty in that calculation, and (3) including uncertainty in the comparisons of the calculated results to the criteria in 10 CFR 50.46(b) to assure a high probability that the criteria would not be exceeded. To be considered acceptable, evaluation models should account for identified sources of heat in performing best-estimate calculations. In particular, the rates of energy release, hydrogen generation, and Zircaloy cladding oxidation from the metal-water reaction of zirconium with steam should be calculated in a best-estimate manner using one of two procedures, depending on the cladding temperature:

(1) If cladding temperature is less than or equal to 1,900 degrees F, correlations to be used to calculate metal-water reaction rates should (1) be checked against a set of relevant data and (2) recognize the effects of steam pressure, preoxidation of the cladding, deformation during oxidation, and internal oxidation from both steam and uranium oxide fuel.

(2) If cladding temperature is greater than 1,900 degrees F, the Cathcart-Pawel equation and the underlying empirical data used to derive it are considered acceptable for calculating the rates of energy release, hydrogen generation, and cladding oxidation.

Alternatively, a conservative evaluation model may be developed in conformance with the required and acceptable features of Appendix K, "ECCS Evaluation Models," to 10 CFR Part 50,

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1 Regulatory Guide (RG) 1.157, "Best-Estimate Calculations of Emergency Core Cooling System Performance," issued May 1989 (ADAMS Accession No. ML003739584), states that "the term 'evaluation model' refers to a nuclear plant system computer code or any other analysis tool designed to predict the aggregate behavior of a reactor during a loss-of-coolant accident. It can be either best-estimate or conservative and may contain many correlations or models."

2 RG 1.157 states that "the terms 'best-estimate' and 'realistic' have the same meaning. Both terms are used to indicate that the techniques attempt to predict realistic reactor system thermal-hydraulic response."

3 RG 1.157 states that "the term 'model' refers to a set of equations derived from fundamental physical laws that is designed to predict the details of a specific phenomenon."

4 RG 1.157 states that "the term 'correlation' refers to an equation having empirically determined constants such that it can predict some details of a specific phenomenon for a limited range of conditions."

"Domestic Licensing of Production and Utilization Facilities." Appendix K requires evaluation models to account for sources of heat during LOCA conditions that are identified in Subpart I.A, "Sources of Heat during the LOCA." In particular, Subpart I.A.5, "Metal-Water Reaction Rate," of Appendix K requires use of the Baker-Just equation to calculate the rates of energy release, hydrogen generation, and Zircaloy cladding oxidation from the metal-water reaction of zirconium with steam, assuming that the reaction is not steam limited.

The petitioner asserted that data from multirod (assembly) severe fuel damage experiments indicate that equations used to calculate the metal-water reaction rate in ECCS evaluation models that the NRC has determined to be acceptable for use in evaluating ECCS cooling performance are not conservative. In particular, the petitioner asserted that data from cited experiments indicate that use of the Cathcart-Pawel equation in realistic evaluation models or use of the Baker-Just equation in conservative evaluation models would: (1) overestimate the temperature at which autocatalytic metal-water oxidation reactions would occur during a LOCA; and (2) underestimate the rate of Zircaloy cladding oxidation from the metal-water reaction of zirconium with steam and, therefore, underestimate the heatup, heatup rate, and maximum temperature of the Zircaloy cladding during a LOCA. Therefore, the petitioner requested the NRC to amend RG 1.157 and 10 CFR Part 50, Appendix K, to require that the rates of energy release, hydrogen generation, and Zircaloy cladding oxidation from the metal-water reaction of zirconium with steam considered in evaluation models used to calculate ECCS cooling performance be calculated based on data from cited experiments, instead of using the Cathcart-Pawel or Baker-Just equations.

*Issue 3: Minimum Allowable Core Reflood Rate*

The regulation at 10 CFR 50.46(b) does not include criteria for calculated ECCS cooling performance pertaining to the core reflood rate following postulated LOCAs. However, the petitioner asserted that a constant core reflood rate of approximately 1 inch per second or lower would not, with high probability, prevent Zircaloy cladding from exceeding the 2,200-degree-F limit in 10 CFR 50.46(b)(1) if, at the onset of reflood, the cladding temperature was greater than or equal to 1,200 degrees F. In particular, the petitioner asserted that: (1) although reflood rates would vary throughout the reactor core during a LOCA, local reflood rates could be approximately 1 inch per second or lower, and (2) extrapolation of data from cited experiments indicates that a constant core reflood rate of approximately 1 inch per second or lower would not, with high probability, prevent Zircaloy cladding from exceeding the 2,200-degree-F limit if the cladding temperature was greater than or equal to 1,200 degrees F at the onset of reflood.[5] Therefore, the petitioner requested the NRC to issue a new regulation that requires minimum allowable core reflood rates in the event of a LOCA.

Public Comments on the Petitions

The NRC received a total of 33 comment submissions that collectively included 125 individual comments over both public comment periods. The staff reviewed and considered all 125 comments in its evaluation of the petitions. These public comments fall into three main categories, as summarized below. These categories are used only to facilitate presenting a high-level summary and counts for the comments that different stakeholder groups submitted;

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5 Extrapolation of the experimental data was necessary because the referenced tests were started with relatively low initial cladding temperatures. The petitioner hypothesized that, if these tests had started with higher initial cladding temperatures, autocatalytic oxidation and failure of the Zircaloy cladding would have occurred with high probability.

the staff used the same approach for addressing all submitted comments, regardless of category or who submitted them. More detailed documentation on the public comments and the agency's response to them is provided in the enclosed draft *Federal Register* notice.

*Category 1: Comments from the Petitioner*

The petitioner, Mark Edward Leyse, provided a total of 13 comment submissions that included approximately 100 individual comments in support of PRM-50-93 and PRM-50-95. He provided nine of these comment submissions after the comment period closed. The staff considered all 13 comment submissions and their individual comments in its evaluation. In general, the petitioner's comments further supported the petitions by either: (1) repeating or reemphasizing information that had already been provided, (2) providing additional details to clarify specific issues, or (3) citing other references that the petitioner believed further substantiate the arguments in the petitions. In some comments, the petitioner identified additional technical issues that were relevant to the subject matter but were not directly related to the requested changes to NRC regulations. As discussed in the section below, the staff addressed these additional technical issues in its final technical safety analysis report (ADAMS Accession No. ML16078A318).

*Category 2: Comments from Nuclear Industry Representatives*

The Nuclear Energy Institute (NEI) provided two comment submissions that oppose PRM-50-93 and PRM-50-95. Overall, NEI recommended that the NRC deny PRM-50-93 and PRM-50-95 because the experiments identified in the petitions—whether considered individually or in conjunction with other experiments—do not substantiate the assertions or requests made in the petitions. NEI further provided additional experimental evidence that indicates that the NRC's regulations and associated regulatory guidance on ECCS acceptance criteria or evaluations models are adequate.

Exelon Corporation provided one comment submission that opposes PRM-50-93 and PRM-50-95, stating that (1) it did not consider the proposed amendments to the NRC's regulations or associated regulatory guidance to be necessary and (2) it agreed with the comments submitted by NEI.

*Category 3: Comments from Public Interest Groups or Other Interested Individuals*

Individuals representing three public interest groups (Don't Waste Michigan, Beyond Nuclear, and Union of Concerned Scientists) each provided one comment submission in support of PRM-50-93 and PRM-50-95. In general, the individual comments provided high-level statements in support of the petitions without citing relevant evidence to substantiate this support.

Other interested individuals provided a total of 10 comment submissions on PRM-50-93 and PRM-50-95. In general, these individual comments also provided high-level statements of support for the petitions without citing relevant evidence to substantiate this support. Several comments identified unrelated concerns about NRC regulations or practices that the staff determined to be outside the scope of PRM-50-93 and PRM-50-95.

Robert Leyse, a relative of petitioner Mark Edward Leyse, provided four comment submissions in support of PRM-50-93 and PRM-50-95. Robert Leyse had previously submitted a related

petition for rulemaking (PRM-50-76) that the NRC denied on September 6, 2005.[6] In general, Robert Leyse's comments supported PRM-50-93 and PRM-50-95 and either repeated information provided in the petitions or expressed his view that the NRC did not appropriately consider all relevant information in its denial of PRM-50-76.

Staff Technical Evaluation

The staff used a special review process to evaluate these petitions. It did this for three main reasons: (1) additional time and resources were needed to reevaluate more than 40 years of severe accident and thermal-hydraulic experimental data from more than 200 technical references to address all arguments in the petitions; (2) to promptly respond to any significant safety issues, if any were to be identified; and (3) to keep the public informed and to publicly address any stakeholder concerns about the adequacy of the NRC's regulations following the accident that occurred in 2011 at the Fukushima Dai-ichi Nuclear Power Station in Japan.

As part of this special review process, the staff made a series of draft interim reports available to the public (ADAMS Accession Nos. ML112290888, ML112650009, ML12265A277, and ML13067A261). These reports informed the public of NRC's progress in evaluating the petitions and included the staff's initial evaluation of specific issues and relevant data that were prioritized to determine the order in which they would be evaluated.

The staff completed its technical evaluation of the petitions and prepared a final technical safety analysis report that documents the official technical basis for the staff's evaluation. This final technical safety analysis report includes the NRC staff's evaluation of: (1) each of the three main issues raised in the petitions; and (2) additional technical issues that are not directly related to the requested changes to the NRC's regulations that were raised in either the petitions or in subsequent communications (e.g., submitted public comments, e-mail messages, letters, and oral statements in a public meeting with the Commission).

The sections that follow summarize the staff's evaluation of each of the three main issues identified in the petitions and identify the relevant section of the final technical safety analysis report that provides additional details to support the staff's position.

*Issue 1: Calculated Maximum Fuel Element Cladding Temperature Limit*

The staff reviewed experimental data and information from the multirod (assembly) severe fuel damage experiments cited in the petitions and found no evidence of temperature escalation rates that demonstrated the occurrence of autocatalytic or runaway oxidation reactions at Zircaloy cladding temperatures less than 2,200 degrees F. Although some rapid temperature increases were observed in the data from the cited experiments, the staff disagrees with the assertion that these data indicate that: (1) autocatalytic metal-water oxidation reactions and uncontrolled temperature excursions involving Zircaloy cladding have occurred at temperatures less than the 2,200-degree-F limit under LOCA conditions, and (2) the 2,200-degree-F limit is

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6 Robert Leyse petitioned the NRC on May 1, 2002, requesting the NRC to amend Appendix K of 10 CFR Part 50 and RG 1.157 to correct asserted technical deficiencies in the Baker-Just and Cathcart-Pawel equations used to calculate the metal-water reaction rate in ECCS evaluation models (ADAMS Accession No. ML022240009). The NRC denied PRM-50-76, determining that: (1) none of the specific technical issues raised by the petitioner showed safety-significant deficiencies in the research, calculation methods, or data used to support ECCS cooling performance evaluations; and (2) the NRC's regulations and regulatory guidance on ECCS cooling performance evaluations were based on sound science and did not need to be amended (70 FR 52893).

therefore not conservative. The staff has further determined that the 2,200-degree-F limit in 10 CFR 50.46(b)(1) provides an adequate margin of safety to preclude autocatalytic metal-water oxidation reactions. Therefore, the staff concludes that the petitioner did not provide sufficient information to support amending 10 CFR 50.46 to require that the calculated maximum fuel element cladding temperature not exceed a limit based on data from cited experiments, instead of the 2,200-degree-F limit in 10 CFR 50.46(b)(1). Section 2.1, "Peak Cladding Temperature Limit is Nonconservative," of the final technical safety analysis report provides additional details to support the staff's position.

*Issue 2: Metal-Water Reaction Rate Equations for Emergency Core Cooling System Evaluation Models*

The staff has determined that (1) use of the Cathcart-Pawel equation generally results in sufficiently accurate calculations of the metal-water reaction rate that are appropriate for realistic ECCS evaluation models and (2) use of the Baker-Just equation results in sufficiently conservative calculations of the metal-water reaction rate that are appropriate for conservative ECCS evaluation models. The final technical safety analysis report also cites several independent studies that provide further support for these findings.

The petitioner relied on two main arguments to support the assertion that the Cathcart-Pawel and Baker-Just equations are not conservative. The first argument was that data from cited multirod (assembly) severe fuel damage experiments indicate both equations are not conservative for use in analyses that calculate the temperature at which an autocatalytic or runaway oxidation reaction involving the Zircaloy cladding would occur in the event of a LOCA. However, the staff disagrees with this argument for two reasons: (1) autocatalytic or runaway oxidation does not begin at a specific temperature; and (2) the petitioner made invalid comparisons between the results of specific experiments and generic calculations that were not intended to be applied to a specific test facility.

The second argument was that the Cathcart-Pawel and Baker-Just equations were not developed to consider how complex thermal-hydraulic phenomena would affect the metal-water reaction rate in the event of a LOCA. However, consistent with the technical safety analysis that was performed for PRM-50-76, the staff determined that—for the development of metal-water reaction rate equations—well-characterized isothermal tests are more important than the complex thermal hydraulics suggested in the petitions. The suggested use of complex thermal-hydraulic conditions would be counterproductive in tests to experimentally derive reaction rate correlations because temperature control is required to develop a consistent set of data for correlation derivation. Isothermal tests provide this necessary temperature control. However, previous studies have applied the derived correlations to transients that include complex thermal-hydraulic conditions to verify that the proposed phenomena embodied in the correlations are limiting. These studies showed that: (1) use of the Cathcart-Pawel equation results in conservative or best-estimate calculations of the metal-water reaction rate, and (2) use of the Baker-Just equation results in conservative calculations of the metal-water reaction rate. Therefore, the staff concludes that the petitioner did not provide sufficient information to support the revision of RG 1.157 and 10 CFR Part 50, Appendix K, to require that the rates of energy release, hydrogen generation, and Zircaloy cladding oxidation from the metal-water reaction of zirconium with steam considered in evaluation models used to calculate ECCS cooling performance be calculated based on data from cited experiments, instead of using the Cathcart-Pawel or Baker-Just equations. Section 2.2, "Baker-Just and Cathcart-Pawel Equations are Nonconservative," of the final technical safety analysis report provides additional details to support the NRC staff's position.

*Issue 3: Minimum Allowable Core Reflood Rate*

The staff's calculations using simulations of a Zircaloy cladding bundle with the geometry and design that was used for the cited multirod (assembly) severe fuel damage experiments disproved the petitioner's assertions about the reflood rate. In particular, calculations using simulations showed that steam cooling would be sufficient to maintain Zircaloy cladding temperatures below the 2,200-degree-F limit in 10 CFR 50.46(b)(1). Moreover, the staff determined that (1) the cooling of a fuel rod bundle depends on several parameters and heat transfer mechanisms rather than on the reflood rate alone, (2) linear extrapolation of initial Zircaloy cladding temperatures to predict final cladding temperature is inappropriate because of increased radiative cooling at higher temperatures, and (3) extrapolation of experimental data does not show "with high probability" that peak cladding temperatures will exceed 2,200 degrees F. Therefore, the staff concludes that the petitioner did not provide sufficient information to support the issuance of a new regulation that requires minimum allowable core reflood rates in the event of a LOCA. Section 2.3, "Need for a Minimum Allowable Reflood Rate," of the final technical safety analysis report provides additional details to support the staff's position.

RECOMMENDATION:

The staff recommends that the Commission deny PRM-50-93 and PRM-50-95 because existing NRC regulations provide reasonable assurance of adequate protection of public health and safety. The petitioner did not present sufficient new information or arguments to support the requested changes. In addition, the staff disagrees with the arguments in the petitions and concludes that the requested amendments to its regulations and associated regulatory guidance are not necessary to ensure public health and safety are adequately protected.

The staff requests the Commission's approval to publish the enclosed draft *Federal Register* notice denying PRM-50-93 and PRM-50-95 (Enclosure 1). The enclosed letter for signature by the Secretary of the Commission (Enclosure 2) informs the petitioner of the Commission's decision to deny the petitions. The staff would also inform the appropriate congressional committees of the Commission's decision.

Additionally, the staff recommends closure of controlled correspondence ticket 201300051, which was issued to ensure that comments the petitioner submitted at a public meeting with the Commission in January 2013 were included in this evaluation. The staff considered and addressed these comments in its final technical safety analysis report. More detailed information about the agency's response to these comments is provided in the enclosed draft *Federal Register* notice.

RESOURCES:

This paper does not address any new commitments or resource implications.

COORDINATION:

The Office of the General Counsel has reviewed this package and has no legal objection to the denial of the petitions.

Victor M. McCree
Executive Director
for Operations

Enclosures:
1. *Federal Register* Notice
2. Letter to the Petitioner

SUBJECT: DENIAL OF PETITIONS FOR RULEMAKING ON CALCULATED MAXIMUM FUEL ELEMENT CLADDING TEMPERATURE (PRM-50-93 AND PRM-50-95; NRC-2009-0554), DATED FEBRUARY 14, 2018.

WITS: 201300051

**ADAMS Accession Nos:** PKG: ML14308A066, SECY: ML14308A138, FRN: ML14308A098, LTR to Pet: ML14308A119 *Concurrence via email

| OFFICE | ADM/PMAE/DAET* | NMSS/DRM/RRPB/PM | NMSS/DRM/RRPB/PM | NMSS/DRM/RRPB/RS | NMSS/DRM/RRPB/BC |
|---|---|---|---|---|---|
| NAME | JDougherty (QTE) | DHudson | DDoyle | GLappert | MKhanna |
| DATE | 11/29/2017 | 12/19/2017 | 12/14/2017 | 12/18/2017 | 12/13/2017 |
| OFFICE | NMSS/DRM/RASB/BC* | NMSS/DRM/D* | RES/D* | NRO/D* | OGC/GCLR/RMR* |
| NAME | CBladey | PHolahan | MWeber, MCase for | FBrown, JMonninger for | MSpencer, SClark for |
| DATE | 12/28/2017 | 12/29/2017 | 01/11/2018 | 01/08/2018 | 02/01/2018 |
| OFFICE | NRR/D* | EDO | | | |
| NAME | BHolian, MEvans for | VMcCree | | | |
| DATE | 02/05/2018 | 02/14/2018 | | | |

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