December 19, 2008

MEMORANDUM TO: Chairman Klein
Commissioner Jaczko
Commissioner Lyons
Commissioner Svinicki

FROM: R. W. Borchardt ***/RA Bruce S. Mallett for/***
Executive Director for Operations

SUBJECT: STATUS OF STAFF ACTIVITIES RELATED TO RULEMAKING ON EMERGENCY CORE COOLING SYSTEM ACCEPTANCE CRITERIA

The purpose of this memorandum is to inform the Commission of the status of staff activities related to rulemaking to establish improved, performance-based, emergency core cooling system (ECCS) acceptance criteria. In the Staff Requirements Memorandum (SRM) for SECY-02-0057, "Update to SECY-01-0133, 'Fourth Status Report on Study of Risk-Informed Changes to the Technical Requirements of 10 CFR Part 50 (Option 3) and Recommendations on Risk-Informed Changes to 10 CFR 50.46 (ECCS Acceptance Criteria),'" dated March 31, 2003, the Commission directed staff to complete the technical basis and move forward with rulemaking to establish improved, performance-based, ECCS acceptance criteria in Title 10, Section 50.46, "Acceptance Criteria for Emergency Core Cooling Systems for Light-Water Nuclear Power Reactors," of the *Code of Federal Regulation*s (10 CFR 50.46). Of the different rulemaking efforts related to 10 CFR 50.46 directed in SRM-SECY-02-0057,[1] this memorandum relates to the rulemaking to establish new ECCS acceptance criteria in 10 CFR 50.46(b). The 10 CFR 50.46(b) rulemaking is separate from the ongoing rulemaking to establish voluntary, risk-informed, ECCS requirements (i.e., transition break size).

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[1] In the Staff Requirements Memorandum (SRM) on SECY-02-0057, "Update to SECY-01-0133, 'Fourth Status Report on Study of Risk-Informed Changes to the Technical Requirements of 10 CFR Part 50 (Option 3) and Recommendations on Risk-Informed Changes to 10 CFR 50.46 ([Emergency Core Cooling System (ECCS)] Acceptance Criteria),'" dated March 31, 2003; the Commission directed the staff to proceed with the following different rulemaking efforts related to 10 CFR 50.46: (1) risk-informed changes to large-break loss-of-coolant accident (LOCA) technical requirements, (2) status of rulemaking to decouple loss-of-offsite-power (LOOP) from large-break LOCA, and (3) rulemaking on ECCS acceptance criteria. A Commission Memorandum addressing the first item and a Commissioners' Assistant Note regarding the status of the second item are expected to be issued this month. This document addresses the third item.

In a May 13, 2008, memorandum from R. W. Borchardt, entitled, “Updated Schedule for Rulemaking - Emergency Core Cooling System Acceptance Criteria” (Agencywide Documents Access and Management System Accession No. ML081260331), the staff informed the Commission of the status of the 10 CFR 50.46(b) rulemaking efforts and outlined a rulemaking approach that included a decision point about the adequacy of the technical basis (WITS item 200800238). Based on comments received from public stakeholders and internal discussions, the staff identified further research needed to enhance the existing technical basis.

Enclosure 1 presents the staff's decision regarding the adequacy of the technical basis. Enclosure 2 provides a summary of the research findings and their potential impact on the existing rule.

Enclosures:
As stated

cc: SECY
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Adequacy of Technical Basis

In the May 13, 2008, memorandum, the staff outlined its plan for rulemaking to revise the 10 CFR 50.46(b) fuel criteria. The status of these activities is as follows:

Item 1: The staff will publish a research information letter (RIL) containing the proposed technical basis in May 2008.

Status: The staff completed this item on May 30, 2008 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML081350225).

Item 2: The staff will publish a NUREG contractor report (CR) containing the supporting data from the testing program in June 2008.

Status: This report was completed in June 2008 and published in July 2008 (ADAMS Accession No. ML082130389).

Item 3: The staff will hold a public workshop in late August 2008 or early September 2008.

Status: The staff completed this item. It held a public workshop on September 24, 2008 (ADAMS Accession No. ML083010496).

Item 4: The staff will discuss its technical basis conclusions with the Advisory Committee on Reactor Safeguards (ACRS) in October 2008.

Status: The staff completed this item. It briefed the ACRS Subcommittee on Materials, Metallurgy, and Reactor Fuels on December 2, 2008, and held a full ACRS briefing on December 4, 2008.

Items 5 and 6 relate to a decision point in the 10 CFR 50.46(b) rulemaking plan. Specifically, if the staff concludes that the technical basis is adequate, then rulemaking would proceed in accordance with the milestone schedule provided in the memorandum; otherwise, the staff would provide the Commission with a description of additional research activities and an estimated schedule for their completion. The basis for the staff's decision follows.

After the staff publicly released the technical basis information in RIL 0801, "Technical Basis for Revision of Embrittlement Criteria in 10 CFR 50.46(b)," issued May 30, 2008, and NUREG/CR-6967, "Cladding Embrittlement during Postulated Loss-of-Coolant Accidents;" it published a *Federal Register* (FR) notice (73 FR 44778) requesting that public stakeholders comment on the adequacy of the technical basis information and identify issues that may arise with respect to experimental data development, regulatory costs, or impacts of potential new requirements. The comments that the staff received are available at www.regulations.gov under U.S. Nuclear Regulatory Commission (NRC) Docket No. NRC-2008-0332. On September 24, 2008, the staff held a public workshop to discuss stakeholder comments on the adequacy of the technical basis (FR notice solicitation) and to give the public and industry

another opportunity to provide further comment and input. The workshop included presentations and open discussion between representatives of the NRC and international regulatory and research agencies, representatives of domestic and international commercial power firms and fuel vendors, and the general public. The meeting summary, including a list of attendees and presentations, is available at ADAMS Accession No. ML083010496.

Based on comments received from public stakeholders and internal discussions, the staff identified the following as areas where further effort is needed to enhance the existing technical basis documented in NUREG/CR-6967 and RIL 0801:

(1) Comprehensive Test Procedures

A detailed and comprehensive set of experimental procedures is required to ensure that the industry uses acceptable laboratory test protocols in the performance of future testing.

(2) Postquench Ductility (PQD) Tests at Intermediate Hydrogen Levels

The current PQD empirical database does not include testing on irradiated cladding segments with hydrogen concentrations from 100–500 parts per million. Further PQD tests are needed in this intermediate range of hydrogen to develop high-confidence regulatory criteria.

(3) Breakaway Oxidation Tests with Varying Temperature Profiles

The current database on breakaway oxidation is from isothermal tests. Variation in temperature profile or thermal cycling may aggravate the breakaway process and needs to be investigated to define future testing requirements.

Because of the complexity and significance of this performance-based rule change and its anticipated impact on licensees, the staff has decided to issue an advance notice of proposed rulemaking (ANPR). The ANPR process is designed to enhance public participation during significant rulemaking campaigns. Benefits of this approach include the following:

- The ANPR process factors public response to rule concept and/or staff requests for additional information into the rulemaking proceeding and into the language of the proposed rule.

- The ANPR process facilitates formal stakeholder interaction on the rulemaking while further research is being acquired.

In addition to the three areas for enhanced technical basis discussed above, the industry plans to conduct an independent loss-of-coolant accident test program (described during the public work- shop and ACRS briefings). The ANPR provides a vehicle to solicit further public comment and independent validation of the comprehensive test procedures during the industry-sponsored tests. The ANPR would include specific requests related to (1) the effectiveness of the test procedures and (2) the results of the industry-sponsored and international test programs. In

addition, the ANPR would solicit feedback on the structure of the performance-based rule, cladding performance criteria, rule language, and periodic testing requirements.

Public stakeholder involvement through the ANPR process should facilitate a more complete and amenable proposed rule and expedite the final rule. To facilitate timely publication of the ANPR, the staff plans to issue it under the authority of the Executive Director of Operations (EDO). If important new information is developed after completing the planned research activities and reviewing stakeholder comments on the ANPR, the staff will inform the Commission and provide updated plans for the completion of the rulemaking. The table below lists the milestones leading to completion of the ANPR and proposed rule. The supplemental experimental data at Argonne National Laboratory should be completed within the next 6 weeks. Documentation and test procedures will follow shortly thereafter.

Milestones	**Schedule**
Completion of technical basis enhancements: (1) Comprehensive test procedures (2) Additional PQD tests (3) Additional breakaway tests	April 1, 2009
EDO signs ANPR for 10 CFR 50.46(b)	July 31, 2009
ANPR published for public comment (75 days)	August 19, 2009
Public comment period closes	November 2, 2009
Provide proposed rule to the Commission	9 months after receipt of ANPR public comments (August 2010)

Summary of LOCA Research Findings

In 10 CFR 50.46(b), the U.S. Nuclear Regulatory Commission (NRC) specifies fuel criteria that ensure that the fuel cladding maintains a degree of postquench ductility (PQD) during a postulated loss-of-coolant accident (LOCA). The current criteria, 2,200 degrees Fahrenheit (ºF) and 17-percent equivalent cladding reacted (ECR), are based on ring-compression tests performed on unirradiated Zircaloy specimens. In 1998, the Office of Nuclear Regulatory Research initiated a LOCA research program to investigate potential burnup and alloying effects on the 10 CFR 50.46(b) fuel criteria. The results of this extensive research program appear in NUREG/CR-6967, "Cladding Embrittlement during Postulated Loss-of-Coolant Accidents," and in Research Information Letter (RIL) 0801, "Technical Basis for Revision of Embrittlement Criteria in 10 CFR 50.46(b)(2)," dated May 30, 2008.

Empirical results and conclusions from the Argonne National Laboratory research program highlight the need to pursue changes to the 10 CFR 50.46(b) fuel criteria. RIL 0801 summarizes the research results as follows:

> The effects on cladding embrittlement of both alloy composition and burnup were studied in the present research program. Alloy composition effects were insignificant, but burnup effects were substantial. Some of the hydrogen that is liberated in the corrosion process enters the cladding during normal operation. The hydrogen was found to produce a strong effect on the embrittlement of the cladding, but the effect is indirect. Hydrogen acts as a catalyst while oxygen, which diffuses into the cladding metal during a LOCA transient, is the direct cause of embrittlement. Oxygen from the oxide fuel pellets was found to enter the cladding from the inside in high-burnup fuel in addition to the oxygen that enters from the oxide layer on the outside of the cladding. Under conditions that might occur during a small-break LOCA, the accumulating oxide on the surface of the cladding can break up and was found to let large amounts of hydrogen into the cladding during the LOCA transient thus exacerbating the embrittlement process. The current work also confirmed an older finding that, if rupture occurs during a LOCA transient, large amounts of hydrogen can enter the cladding from the inside near the rupture location.

The LOCA research program identified new cladding embrittlement mechanisms and expanded our knowledge of previously identified mechanisms. The table on the next page summarizes the key research findings as they relate to current 10 CFR 50.46(b) regulations. Although rule changes are necessary to address deficiencies within the current cladding embrittlement criteria in 10 CFR 50.46(b), current operating plants appear to maintain sufficient safety margin such that public health and safety are not compromised. The basis of this safety assessment is documented in Agencywide Documents Access and Management System Accession No. ML081620302.

LOCA Research Impact on Current Regulations

Current Regulation	Research Finding	Impacts
10 CFR 50.46(a)(1)(i): Applicability limited to, "[Z]ircaloy or ZIRLO™"	Testing included many different zirconium alloys. RIL 0801 concludes that PQD is alloy-independent and that breakaway is alloy-dependent.	Applicability may be expanded beyond Zircaloy and ZIRLO™.
10 CFR 50.46(b)(1): Peak cladding temperature, "shall not exceed 2,200 °F."	PQD test results confirm an upper temperature limit (i.e., cladding ductility is lost quickly above 2,200 °F).	Maintain the current regulation.
10 CFR 50.46(b)(2): Maximum cladding oxidation, "shall nowhere exceed 0.17 times the total cladding thickness before oxidation."	PQD test results identified new embrittlement mechanisms that promote a lower allowable time-at-temperature limit (expressed as Cathcart-Pawel (CP) ECR) as a function of initial hydrogen content.	A single prescriptive local oxidation limit is no longer possible. CP-ECR must be used in LOCA analyses to correlate time-at-temperature embrittlement to empirical database. Correct the improper use of CP within best estimate LOCA methods along with 17% ECR criterion (based on Baker-Just).
10 CFR 50.46(b)(3): Maximum hydrogen generation	Not addressed	None
10 CFR 50.46(b)(4): Coolable geometry	The investigation and characterization of the fuel rod balloon are beyond the scope of the current program.	None
10 CFR 50.46(b)(5): Long-term cooling	Not addressed	None
Not applicable (NA)	LOCA testing identified a new mechanism involving breakaway oxidation (i.e., unstable oxide transformation and growth).	New regulatory criteria are required for maximum time duration above a temperature where unstable oxide was observed in testing. New analytical requirement for break-spectrum analysis on maximizing time above 1,200 °F
NA	Oxygen diffusion from cladding inside diameter was detected in tests with high burnup fuel rods.	New language within 10 CFR 50.46; Appendix K, "ECCS Evaluation Models," to 10 CFR Part 50; or regulatory guidance documents is needed to require double-sided CP-ECR (beyond a burnup threshold) in areas beyond the balloon/burst node.

Current Regulation	Research Finding	Impacts
NA	LOCA integral tests confirm that in the vicinity of the fuel rod rupture node, the cladding quickly becomes embrittled as a result of gross hydrogen uptake.	The 10 CFR 50.46(b)(2) criterion may not protect (i.e., ensure PQD) this portion of the fuel rod. Further research is required.
NA	Recent tests at Halden have reaffirmed the staff's position with respect to fuel relocation.	Fuel fragment packing within the balloon region may need to be accounted for in LOCA analyses. Further research is required.