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MEMORANDUM TO: Christopher Van Wert, Senior Technical Advisor for Reactor Fuel
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SUBJECT: 50.46C ECCS SAFETY ASSESSMENT: 2022 - 2023 UPDATE

The purpose of this memorandum is to provide an annual update to the 50.46c emergency core cooling system (ECCS) performance safety assessment. This update captures ECCS model changes and errors reported within the 50.46(a)(3) annual and 30-day reports and new loss-of-coolant accident (LOCA) analysis-of-record. The 50.46c ECCS performance safety assessment documents plant-specific safety margin relative to the proposed requirements, confirms continued safe operation for the entire fleet, and informs the implementation plan for the proposed 10 CFR 50.46c rule.

Enclosure:
2022 - 2023 ECCS Performance Safety

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DATED: January 31, 2024

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2022 - 2023 50.46c ECCS Performance Safety Assessment

1. Scope and Purpose

The purpose of this memorandum is to provide an annual update to the 50.46c ECCS performance safety assessment. This update captures ECCS model changes and errors reported within the 50.46(a)(3) annual and 30-day reports as well as new LOCA analysis-of-record. The 50.46c ECCS performance safety assessment documents plant-specific safety margin relative to the proposed requirements, confirms continued safe operation for the entire fleet, and informs the implementation plan for the proposed 10 CFR 50.46c rule.

In response to the research findings in Research Information Letter (RIL) 0801, "Technical Basis for Revision of Embrittlement Criteria in 10 CFR 50.46," (ADAMS Accession No. ML081350225), the staff performed a preliminary safety assessment of currently operating reactors (ADAMS Accession No. ML081620302 Proprietary, ML090340073 Non-Proprietary). This assessment found that, due to measured cladding performance under loss-of-coolant accident (LOCA) conditions, realistic fuel rod power history, and current analytical conservatisms, sufficient safety margin exists for operating reactors. Therefore, the NRC staff determined that immediate regulatory action was not required, and that changes to the emergency core cooling system (ECCS) acceptance criteria to account for these new findings can reasonably be addressed through the rulemaking process.

Recognizing that finalization and implementation of the new ECCS requirements would take several years, the staff decided that a more detailed safety assessment was necessary. Working with the PWROG and BWROG, the staff completed a comprehensive ECCS performance safety assessment which confirmed, on a plant-specific basis, the safe operation of the U.S. commercial nuclear fleet. The ECCS performance safety assessment was issued in a memorandum dated September 27, 2011 (ADAMS Accession number ML11262A017) along with the staff's audit report of the PWR Owners Group (ADAMS Accession No. ML11140A159) and BWR Owners Group (ADAMS Accession No. ML111950139) ECCS margin assessment reports.

The 2011 ECCS performance safety assessment represents a snapshot of the available post-quench ductility (PQD) and breakaway oxidation margin at the time the plant specific information was compiled. Since that time, changes to and errors discovered in ECCS models, as well as planned license amendment requests (e.g., power uprates, fuel transitions), challenge the continued applicability of the 2011 ECCS performance safety assessment. To ensure continued safe operation until the proposed 10 CFR 50.46c requirements are implemented, DSS committed to perform annual updates.

2. ECCS Performance Safety Assessment

In accordance with 10 CFR 50.46(a)(3)(iii), licensees are required to report any "change to or error discovered in an acceptable evaluation model or in the application of such a model that affects the temperature calculation." Within these reports, the licensee provides a 'rack up' of the changes and errors including an 'estimated' change in peak cladding temperature (PCT). The current regulation does not require an estimate to the previously reported maximum local oxidation. Note that the proposed 50.46c rule requires reporting changes in ECR.

The following assumptions were used in assessing the impact of reported changes and errors on available ECR margin:

1. If no errors or changes were reported (i.e., PCT unchanged), then prior annual ECCS margin assessment remains applicable.

2. If summation of estimated impacts of errors and changes equaled zero (i.e., PCT unchanged), then prior annual ECCS margin assessment remains applicable.

3. If summation of estimated impacts of errors and changes was negative (i.e., PCT reduced), then prior annual ECCS margin assessment remains applicable.

4. If summation of estimated impacts of errors and changes was positive (i.e., PCT increased), then an assessment of residual ECCS margin was performed.

If an assessment of residual ECCS margin is necessary, then the change in CP-ECR (ΔECR) is estimated based upon reported changes in PCT. The following steps are taken to complete the annual assessment.

1. If a new ECCS calculation was performed during past 12 months (e.g., LAR involving ECCS), then record predicted PCT, ECR, burst/no burst, and time above 800C. Update AOR portion of ECCS margin database.

2. Compute margin relative to proposed requirements (alloy-specific). Update margin assessment portion of ECCS margin database.

3. Assess need for analytical credits, similar to Owner's Group margin report. Update Owners Group portion of ECCS margin database.

-- OR –

1. Record the estimated change in PCT from 50.46(a)(3) reports.

2. Record the predicted time above 1600 °F for the limiting UFSAR AOR transient scenario (separate SB and LB for PWRs)

3. If burst predicted, perform 2-sided ECR calculation assuming 30% strain. Otherwise, 1-sided ECR calculation.

4. As shown in Figure 2-1, perform ECR calculation for simplified AOR (10degC ramp up to PCT, hold for time duration above 1600F, followed by 10 degC ramp down)

5. As shown in Figure 2-1, perform ECR calculation for modified AOR (10degC ramp up to new estimated PCT, hold for time duration above 1600F, followed by 10 degC ramp down)

6. ΔECR = ECR (step 5) - ECR (step 4)

7. ECR Margin = ECR Margin (previous assessment) - ΔECR (step 6)

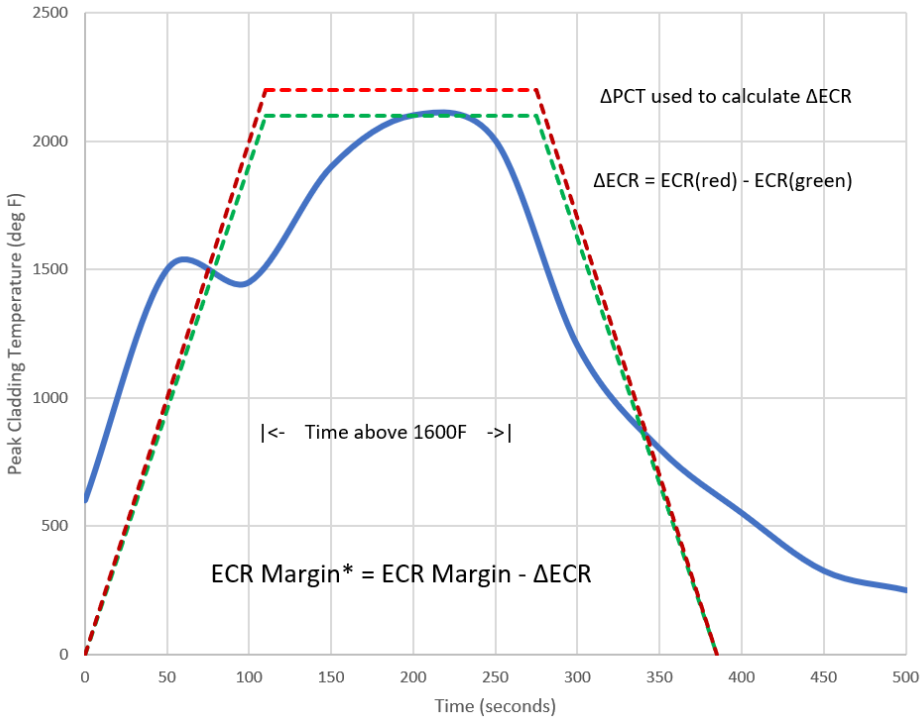
8. If positive ECR margin exists, then assessment complete. If negative margin exists, then investigate possible analytical credits (similar to OG report), perform a more detailed ΔECR assessment, or contact the licensee or fuel vendor.

9. Evaluate breakaway oxidation margin.

A simplified ΔECR calculation is necessary since the impact of the change/error on the accident progression and time-temperature history is unknown. The above simplified ΔECR calculation is inherently conservative since the duration at the peak temperature is artificially extended for both the simplified AOR PCT and the estimated PCT. Thus, maximizing the ΔECR calculation. This is illustrated in Figure 2-1 where the solid blue line represents the actual AOR peak cladding temperature profile and the dotted lines represent the simplified temperature profiles. For each plant, the updated ECCS Margin Database provides the following information:

- Plant design
- Licensed power
- Fuel vendor
- Fuel rod cladding alloy
- Evaluation model
- AOR results (calculated PCT, MLO, and time above 800°C)
- Plant grouping
- Rebaseline ECR (if available)
- Margin to PQD analytical limit
- Margin to breakaway oxidation analytical limit
- Identify analytical credit(s)
- New AOR (Y/N)
- Reported changes
- Impact on margin assessment
- ADAMS number of 50.46(a)(3) report

Figure 2-1: Estimated Change in ECR Margin



2022 – 2023 Annual Update:

The ECCS margin database was updated to capture all 50.46(a)(3)(iii) reports and relevant LARs over the period from January 2022 to January 2023. In summary, the following impacts were reported:

Boiling Water Reactors (31 total reactors):

- 23 plants reported no change in PCT
- 0 plants reported a reduction in PCT
- 5 plants reported an increase in PCT
- 3 plants revised LOCA AOR

Pressurized Water Reactors (64 total reactors):

Large Break LOCA:

- 59 plants reported no change in PCT
- 0 plants reported a reduction in PCT
- 1 plant reported an increase in PCT
- 4 plants revised LOCA AOR

Small Break LOCA:

- 55 plants reported no change in PCT
- 0 plants reported a reduction in PCT
- 1 plant reported an increase in PCT
- 8 plants revised LOCA AOR

The revised database is listed below. Table 2-1 provides a record of revision for the ECCS margin database.

ECCS_Margin_Database_2022_2023_r0.pdf

Examination of the 2022-2023 ECCS Margin Database reveals that the majority of plants needed no adjustments to show a positive margin to the revised analytical limits. In summary:

Revised PQD Analytical Limit:

- For BWRs, 30 of 31 plants (97% of BWR fleet) needed no adjustment or new calculations:
    - Remaining BWR performed new LOCA calculations which credit COLR Thermal-Mechanical Operating Limits (TMOL) reduced rod power at higher burnup to satisfy new analytical limits.
    - No change from 2021-2022 margin assessment
- For PWR small break LOCA, 62 of 64 plants (97% of PWR fleet) needed no adjustment or new calculations:
    - Remaining 2 PWRs credit rod peaking factor burndown
    - No change from 2021-2022 margin assessment
- For PWR large break LOCA, 44 of 64 plants (69% of PWR fleet) needed no adjustment or new calculations:
    - Remaining 20 PWRs credit either new LOCA calculations (including rebase lined PCTs) or identified credits to satisfy new analytical limits.
    - Reduction from 23 plants in 2021-2022 margin assessment

New Breakaway Oxidation Analytical Limit:

- All 95 plants needed no adjustments or new calculations
    - No plants had a time-at-temperature duration greater than 2000 seconds.
    - Oyster Creek (shutdown in 2019) was the only plant with minimal margin.

Table 2-1: 50.46c ECCS Margin Database Record of Revision

Revision	Date	Database	Description
0	9/2011	ECCS_Margin_Database	Initial release. Data collected from PWROG Report OG-11-143, BWROG Report TP-11-010, and via vendor audits.
1	9/2012	ECCS_Margin_Database_ Sept2012	1st annual revision. PWR LBLOCA and SBLOCA assessments separated. Revisions to AOR and error reports captured. ECR tables added to assess impact of PCT change on CP-ECR.
1a	10/2012	ECCS_Margin_Database_ Sept2012_r1	Revise dECR/dT calculations with corrected cladding thickness. Added ECR estimates for SBLOCA based on bounding 1000 second time-at-temperature.
2	9/2013	ECCS_Margin_Database_ Sept2013_r0	2nd annual revision. Revisions to AOR and 50.46 change/error reports captured. dECR calculated based upon dPCT and AOR time-at-temperature profile.
2a	1/2014	ECCS_Margin_Database_ 2013_r1	Capture revision to PWROG margina assessment (PA-ASC-1094). Westinghouse evaluated impact of TCD and past rack-ups, documented new credits, and re-grouped plants.
3	1/2015	ECCS_Margin_Database_ 2014_r0	3rd annual revision. Revisions to AOR and 50.46 change/error reports captured. Added fuel type and accession numbers.
4	1/2016	ECCS_Margin_Database_ 2015_r0	4th annual revision. Revisions to AOR and 50.46 change/error reports captured.
5	1/2017	ECCS_Margin_Database_ 2016_r0	5th annual revision. Revisions to AOR and 50.46 change/error reports captured. Incorporated revised PWROG margin assessment, PWROG-16057-NP, including information gathered during audits. Revised PWROG report evaluated past rack-up, identified new credits, and re-grouped plants.
6	1/2018	ECCS_Margin_Database_ 2017_r0	6th annual revision. Revisions to AOR and 50.46 change/error reports captured.
7	10/2019	ECCS_Margin_Database_ 2018_r0	7th annual revision. Revisions to AOR and 50.46 change/error reports captured.

8	9/2020	ECCS_Margin_Database_2019_r0	8th annual revision. Revisions to AOR and 50.46 change/error reports captured.
9	12/2021	ECCS_Margin_Database_2020_2021_r0	9th annual revision. Revisions to AOR and 50.46 change/error reports captured.
10	1/2023	ECCS_Margin_Database_2021_2022_r0	10th annual revision. Revisions to AOR and 50.46 change/error reports captured
11	7/2024	ECCS_Margin_Database_2022_2023_r0	11th annual revision. Revisions to AOR and 50.46 change/error reports captured

4. Conclusion

The staff's ECCS performance safety assessment represents a snapshot of the available post quench ductility (PQD) and breakaway oxidation margin at the time the plant specific information was compiled. Changes to and errors discovered in ECCS models, as well as planned license amendment requests (e.g., power uprates, fuel transitions), challenge the continued applicability of the ECCS performance safety assessment. To ensure continued safe operation until the proposed 10 CFR 50.46c requirements are implemented, DSS committed to perform annual updates.

The ECCS Margin Database has been updated to capture reported changes and error as well as any new LOCA AORs. The revised database is available in ADAMS.

ECCS_Margin_Database_2022_2023_r0.pdf

Section 2.0 summarizes the impact of these changes on available ECCS performance margin. All plants show positive margin to the proposed 50.46c analytical limits. As such, a coolable core geometry would have been preserved in the event of a postulated LOCA.

In conclusion, the staff has updated the 50.46c ECCS performance safety assessment, captured the latest results and changes, and confirmed safe operation of all nuclear power plants with respect to the new, proposed requirements.