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MEMORANDUM TO: Mirela Gavrilas, Director  
Division of Safety Systems  
Office of Nuclear Reactor Regulation

FROM: Paul M. Clifford, Senior Technical Advisor */RA/*  
Division of Safety Systems  
Office of Nuclear Reactor Regulation

SUBJECT: **50.46C EMERGENCY CORE COOLING SYSTEM SAFETY  
ASSESSMENT – 2017 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 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 Title 10 of the *Code of Federal Regulations*, Section 50.46c rule.

Enclosure:  
2017 ECCS Performance Safety Assessment

CONTACT: Paul. M. Clifford NRR/ADES/DSS  
(301) 415-4043

M. Gavrilas

SUBJECT: 50.46C EMERGENCY CORE COOLING SYSTEM SAFETY ASSESSMENT – 2017  
UPDATE Dated: February 8, 2018

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OFFICE	NRR/DSS	NRR/DSS
NAME	PClifford	
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## **2017 50.46c Emergency Core Cooling System Performance Safety Assessment**

### **1. Scope and Purpose**

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 as well as 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 Title 10 of the *Code of Federal Regulations* (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," (Agencywide Documents Access Management System (ADAMS) Accession No. ML081350225), the staff performed a preliminary safety assessment of currently operating reactors (ADAMS Accession No. ML081620302 Proprietary, ADAMS Accession No. ML090340073 Non-Proprietary). This assessment found that, due to measured cladding performance under LOCA conditions, realistic fuel rod power history, and current analytical conservatisms, sufficient safety margin exists for operating reactors. Therefore, the U.S. Nuclear Regulatory Commission staff determined that immediate regulatory action was not required, and that changes to the 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 Pressure Water Reactors Owners Group (PWROG) and Boiling Water Reactors Owners Group (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 No. ML11262A017) along with the staff's audit report of the PWROG (ADAMS Accession No. ML11139A3090) and BWROG (ADAMS Accession No. ML1119501390) 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, Division of Safety Systems (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 ( $\Delta$ ECR) 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.  $\Delta$ ECR = ECR (step 5) - ECR (step 4)
7. ECR Margin = ECR Margin (previous assessment) -  $\Delta$ ECR (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  $\Delta$ ECR assessment, or contact the licensee or fuel vendor.
9. Evaluate breakaway oxidation margin.

A simplified  $\Delta$ ECR calculation is necessary since the impact of the change/error on the accident progression and time-temperature history is unknown. The above simplified  $\Delta$ ECR calculation is inherently conservative since the duration at the peak temperature is artificially extended for both the simplified abnormal occurrence report (AOR) PCT and the estimated PCT. Thus, maximizing the  $\Delta$ ECR 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

**2017 Annual Update:**

The ECCS Margin Database was updated to capture all 50.46(a)(3)(iii) reports and relevant LARs over the period from December 2016 to December 2017. In summary, the following impacts were reported:

Boiling Water Reactors (34 total reactors)

- 20 plants reported no change in PCT.
- 3 plants reported a reduction in PCT.
- 6 plants reported an increase in PCT.
- 5 plants revised LOCA AOR.

Pressurized Water Reactors (66 total reactors)

LBLOCA:

- 64 plants reported no change in PCT.
- 0 plants reported a reduction in PCT.
- 2 plants reported an increase in PCT.
- 0 plants revised LOCA AOR.

SBLOCA:

- 65 plants reported no change in PCT.
- 0 plants reported a reduction in PCT.
- 1 plants reported an increase in PCT.
- 0 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\_2017\_r0.xlsx (ADAMS Accession No. ML18039A103)

Examination of the 2017 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:

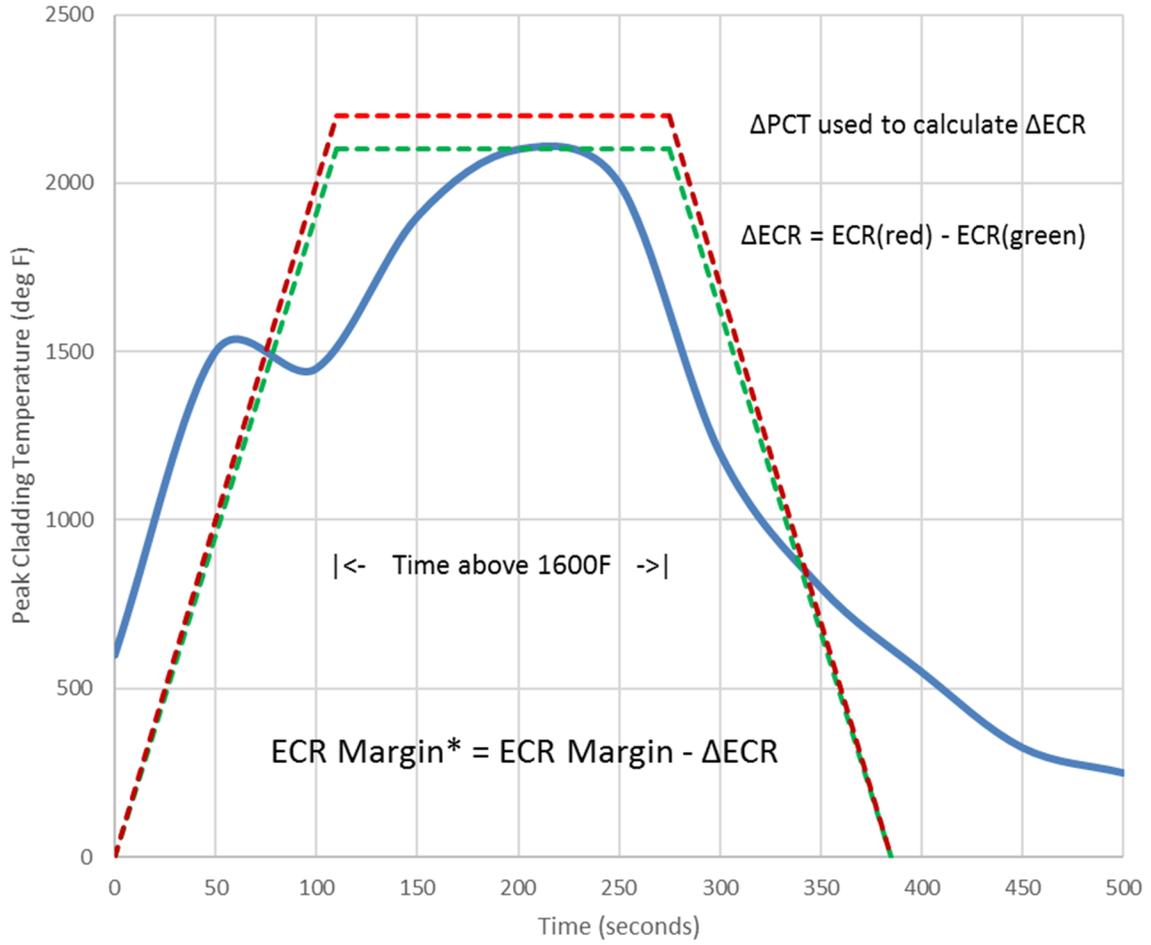
- For BWRs, 26 of 34 plants (76% of BWR fleet) needed no adjustment or new calculations:
  - Remaining 8 BWRs performed new LOCA calculations which credit COLR Thermal-Mechanical Operating Limits (TMOL) reduced rod power at higher burnup to satisfy new analytical limits.
  - No change from 2016 margin assessment.
- For PWR SBLOCA, 55 of 66 plants (83% of PWR fleet) needed no adjustment or new calculations:
  - Remaining 11 PWRs credit rod peaking factor burn down.
  - No change from 2016 margin assessment.

- For PWR LBLOCA, 34 of 66 plants (52% of PWR fleet) needed no adjustment or new calculations:
  - Remaining 32 PWRs credit either new LOCA calculations (including rebaselined PCTs) or identified credits to satisfy new analytical limits.
  - No change from 2016 margin assessment.

New Breakaway Oxidation Analytical Limit:

- All 100 plants needed no adjustments or new calculations.
  - Only 1 plant had time-at-temperature duration above 2000 seconds.
  - No change from 2016 margin assessment.

Figure 2-1: Estimated Change in ECR Margin



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

<b>Revision</b>	<b>Date</b>	<b>Database</b>	<b>Description</b>
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	First 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	Second 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_Sept2013_r1	Capture revision to PWROG margin 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	Third 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	Fourth annual revision. Revisions to AOR and 50.46 change/error reports captured.
5	1/2017	ECCS_Margin_Database_2016_r0	Fifth 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. Both SBLOCA and LBLOCA assessed.
6	1/2018	ECCS_Margin_Database_2017_r0	Sixth annual revision. Revisions to AOR and 50.46 change/error reports captured.

### **3. Conclusion**

The staff's ECCS performance safety assessment represents a snapshot of the available 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\_2017\_r0.xlsx (ADAMS Accession No. ML18039A103)

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.