

10 CFR 50.46

March 18, 2020

U.S. Nuclear Regulatory Commission  
Attn: Document Control Desk  
Washington, DC 20555-0001

Calvert Cliffs Nuclear Power Plant, Units 1 and 2  
Renewed Facility Operating License Nos. DPR-53 and DPR-69  
NRC Docket Nos. 50-317 and 50-318

Subject: 10 CFR 50.46 Annual Report

- References:
- 1) Letter from James Barstow (Exelon) to U.S. NRC, "10 CFR 50.46 Annual Report," dated March 18, 2019.
  - 2) FSI-0048685-1.0, "Framatome's 2019 50.46 Annual Reporting for Calvert Cliffs," February 18, 2020

The purpose of this letter is to submit the 10 CFR 50.46 annual reporting information for Calvert Cliffs Nuclear Power Plant (CCNPP) Units 1 and 2. Reference 1 is the most recent annual 10 CFR 50.46 Annual Report submitted to the U.S. NRC. Reference 2 documents Framatome's annual summary deliverable to Exelon Generation Company, LLC (Exelon) to support this 10 CFR 50.46 annual report.

There were no errors or changes reported against the Unit 1 and Unit 2 Small Break Loss-of-Coolant Accident (SBLOCA) Evaluation Model during the previous reporting period.

Since Reference 1, there was one error reported against the Calvert Cliffs Unit 1 and Unit 2 Realistic Large Break Loss-of-Coolant Accident (RLBLOCA) Evaluation Model used to establish the Analysis of Record (AOR) PCT in 2019 (Reference 2). The error involves an issue with the implementation of the Cathcart-Pawel correlation. This error had a 0°F PCT impact for Calvert Cliffs Unit 1 and Unit 2 RLBLOCA Evaluation model. This is further discussed in Note 13 of Attachment 2.

Two attachments are included with this letter that provide the current CCNPP 10 CFR 50.46 status. Attachment 1 provides the PCT "rack-up" sheets for the Unit 1 and Unit 2 Loss-of-Coolant Accident (LOCA) analyses. Attachment 2, "Assessment Notes," contains a detailed description of each model assessment and error reported.

There are no commitments contained in this letter. If you have any questions, please contact Frank Mascitelli at 610-765-5512.

Respectfully,



---

David P. Helker  
Sr. Manager, Licensing  
Exelon Generation Company, LLC

Attachments: 1) Peak Cladding Temperature Rack-Up Sheets for CCNPP,  
Units 1 and 2  
2) Assessment Notes

cc: USNRC Administrator, Region I  
USNRC Project Manager, CCNPP  
USNRC Senior Resident Inspector, CCNPP  
D. Tancabel, Maryland DNR

**ATTACHMENT 1**

**10 CFR 50.46**

**"Acceptance criteria for emergency core cooling systems  
for light-water nuclear power reactors"**

**Annual Report of the Emergency Core Cooling System  
Evaluation Model Changes and Errors**

**Assessments as of March 18, 2020**

**Peak Cladding Temperature Rack-Up Sheets for**

**CCNPP, Units 1 and 2**

PLANT NAME: Calvert Cliffs Unit 1  
ECCS EVALUATION MODEL: Small Break Loss of Coolant Accident (SBLOCA)  
REPORT REVISION DATE: 03/18/2020  
CURRENT OPERATING CYCLE: 25

## ANALYSIS OF RECORD (AOR)

Evaluation Model: EMF-2328(P)(A), Revision 0, Supplement 1(P)(A), Revision 0  
Calculation: ANP-3641, March 2018  
Fuel: HTP 14 x 14 M5®  
Limiting Fuel Type: HTP 14 x 14 M5®  
Limiting Single Failure: Loss of one emergency diesel generator  
Limiting Break Size and Location: 0.34 ft<sup>2</sup> Break in the Cold Leg Pump Discharge  
Reference Peak Cladding Temperature (PCT) PCT = 1648°F

## MARGIN ALLOCATION

### A. PRIOR LOSS OF COOLANT ACCIDENT (LOCA) MODEL ASSESSMENTS-Note 12

EMF-2328(P)(A), Revision 0, Supplement 1(P)(A), Revision 0	$\Delta PCT = 0^{\circ}F$
Total PCT change from current assessments	$\sum \Delta PCT = 0^{\circ}F$
Cumulative PCT change from current assessments	$\sum  \Delta PCT  = 0^{\circ}F$

NET PCT

PCT = 1648°F

### B. CURRENT LOCA MODEL ASSESSMENTS

None	$\Delta PCT = 0^{\circ}F$
Total PCT change from current assessments	$\sum \Delta PCT = 0^{\circ}F$
Cumulative PCT change from current assessments	$\sum  \Delta PCT  = 0^{\circ}F$

NET PCT

PCT = 1648°F

PLANT NAME: Calvert Cliffs Unit 1  
ECCS EVALUATION MODEL: Realistic Large Break Loss of Coolant Accident (RLBLOCA)  
REPORT REVISION DATE: 03/18/2020  
CURRENT OPERATING CYCLE: 25

## AOR

Evaluation Model: EMF-2103(P)(A)  
Calculation: ANP-3043(P), December 2011  
Fuel: HTP 14 x 14 M5®  
Limiting Fuel Type: HTP 14 x 14 M5®  
Limiting Single Failure: Loss of one emergency diesel generator  
Limiting Break Size and Location: Guillotine break (4.5832 ft<sup>2</sup>/side) in Cold Leg Pump Discharge  
Reference PCT PCT = 1620°F

## MARGIN ALLOCATION

### A. PRIOR LOCA MODEL ASSESSMENTS

10 CFR 50.46 report dated March 20, 2014 (Note 5)	$\Delta PCT = 14\text{ }^{\circ}\text{F}$
10 CFR 50.46 report dated April 23, 2014 (Note 6)	$\Delta PCT = 0\text{ }^{\circ}\text{F}$
10 CFR 50.46 report dated July 14, 2015 (Note 7)	$\Delta PCT = 0\text{ }^{\circ}\text{F}$
10 CFR 50.46 report dated March 18, 2016 (Note 8)	$\Delta PCT = 0\text{ }^{\circ}\text{F}$

NET PCT

PCT = 1634°F

### B. CURRENT LOCA MODEL ASSESSMENTS

10 CFR 50.46 report dated October 1, 2019 (Note 13)	$\Delta PCT = 0\text{ }^{\circ}\text{F}$
Total PCT change from current assessments	$\sum \Delta PCT = 0\text{ }^{\circ}\text{F}$
Cumulative PCT change from current assessments	$\sum  \Delta PCT  = 0\text{ }^{\circ}\text{F}$

NET PCT

PCT = 1634°F

PLANT NAME: Calvert Cliffs Unit 2  
ECCS EVALUATION MODEL: Small Break Loss of Coolant Accident (SBLOCA)  
REPORT REVISION DATE: 03/18/2020  
CURRENT OPERATING CYCLE: 23

## AOR

Evaluation Model: EMF-2328(P)(A), Revision 0, Supplement 1(P)(A), Revision 0  
Calculation: ANP-3641, March 2018  
Fuel: HTP 14 x 14 M5®  
Limiting Fuel Type: HTP 14 x 14 M5®  
Limiting Single Failure: Loss of one emergency diesel generator  
Limiting Break Size and Location: 0.34 ft² break in the Cold Leg Pump Discharge  
Reference PCT PCT = 1648°F

## MARGIN ALLOCATION

### A. PRIOR LOSS OF COOLANT ACCIDENT (LOCA) MODEL ASSESSMENTS – Note 12

EMF-2328(P)(A), Revision 0, Supplement 1(P)(A), Revision 0	$\Delta PCT = 0^{\circ}F$
Total PCT change from current assessments	$\sum \Delta PCT = 0^{\circ}F$
Cumulative PCT change from current assessments	$\sum  \Delta PCT  = 0^{\circ}F$

NET PCT PCT = 1648°F

### B. CURRENT LOCA MODEL ASSESSMENTS

None	$\Delta PCT = 0^{\circ}F$
Total PCT change from current assessments	$\sum \Delta PCT = 0^{\circ}F$
Cumulative PCT change from current assessments	$\sum  \Delta PCT  = 0^{\circ}F$

NET PCT PCT = 1648°F

PLANT NAME: Calvert Cliffs Unit 2  
ECCS EVALUATION MODEL: Realistic Large Break Loss of Coolant Accident (RLBLOCA)  
REPORT REVISION DATE: 03/18/2020  
CURRENT OPERATING CYCLE: 23

## AOR

Evaluation Model: EMF-2103(P)(A)  
Calculation: ANP-3043(P), December 2011  
Fuel: HTP 14 x 14 M5®  
Limiting Fuel Type: HTP 14 x 14 M5®  
Limiting Single Failure: Loss of one emergency diesel generator  
Limiting Break Size and Location: Guillotine break (4.5832 ft<sup>2</sup>/side) in the Cold Leg  
Pump Discharge  
Reference PCT PCT = 1620°F

## MARGIN ALLOCATION

### A. PRIOR LOSS OF COOLANT ACCIDENT (LOCA) MODEL ASSESSMENTS

10 CFR 50.46 report dated April 22, 2013 (Note 4)	$\Delta PCT = 8^{\circ}F$
10 CFR 50.46 report dated March 20, 2014 (Note 5)	$\Delta PCT = 6^{\circ}F$
10 CFR 50.46 report dated April 23, 2014 (Note 6)	$\Delta PCT = 0^{\circ}F$
10 CFR 50.46 report dated July 14, 2015 (Note 7)	$\Delta PCT = 0^{\circ}F$
10 CFR 50.46 report dated March 18, 2016 (Note 8)	$\Delta PCT = 0^{\circ}F$

NET PCT

PCT = 1634°F

### B. CURRENT LOCA MODEL ASSESSMENTS

10 CFR 50.46 report dated October 1, 2019 (Note 13)	$\Delta PCT = 0^{\circ}F$
Total PCT change from current assessments	$\sum \Delta PCT = 0^{\circ}F$
Cumulative PCT change from current assessments	$\sum  \Delta PCT  = 0^{\circ}F$

NET PCT

PCT = 1634°F

**ATTACHMENT 2**

**10 CFR 50.46**

**“Acceptance criteria for emergency core cooling systems  
for light-water nuclear power reactors”**

**Annual Report of the Emergency Core Cooling System  
Evaluation Model Changes and Errors**

**Assessments as of March 18, 2020**

**Assessment Notes**

**CCNPP, Units 1 and 2**



1. Prior LOCA Model Assessment

The 10 CFR 50.46 30-day report dated March 31, 2011 reported new analyses for (ANP-2834) RLBLOCA and (ANP-2871) SBLOCA applicable to Unit 2, Cycle 19. The licensing basis PCT value for Realistic Large Break LOCA (RLBLOCA) and Small Break (SBLOCA) reported was 1670°F and 1626°F, respectively. The analyses were done to support the transition from Westinghouse to AREVA-designed fuel. Unit 2 operation during 2014 uses the RLBLOCA Evaluation Model as summarized in ANP-3043(P). The PCT for RLBLOCA for Unit 2 is 1620°F.

2. Prior LOCA Model Assessment

The 10 CFR 50.46 30-day report dated January 19, 2012 reported an error in the S-RELAP5 Sleicher-Rouse correlation used for predicting heat transfer to single-phase vapor heat transfer. Preliminary assessments of the potential impact of using the alternate Sleicher-Rouse correlation were performed. The SBLOCA assessment resulted in a 69°F PCT impact to Calvert Cliffs Unit 2 (ANP-2871) SBLOCA. (ANP-2834) RLBLOCA was impacted by this correction, however it did not reach the 30-day reporting threshold (50°F PCT impact), therefore it was transmitted in the 2012 annual letter (See Note 3).

3. Prior LOCA Model Assessment

The 10 CFR 50.46 combined 30-day and annual report dated April 30, 2012 reported a new licensing basis PCT for Calvert Cliffs Unit 1 and errors, respectively. The 30-day report changed the (ANP-2834) RLBLOCA and (ANP-2871) SBLOCA, applicable to Unit 1, Cycle 21, licensing basis PCT to 1670°F and 1626°F, respectively. The 10 CFR 50.46 annual report transmitted 3 errors. A steam generator tube liquid entrainment modeling error resulted in a 0°F PCT impact to Calvert Cliffs Unit 1 and 2 (ANP-2834) RLBLOCA. Liquid fallback from the upper plenum to the hot channel resulted in a 0°F PCT impact to Calvert Cliffs Unit 1 and 2 (ANP-2834) RLBLOCA. An error in the S-RELAP5 Sleicher-Rouse correlation used for predicting the heat transfer to single-phase vapor heat transfer, as reported for SBLOCA in the 10 CFR 50.46 30-day report dated January 19, 2012 (Note 2) resulted in a 69°F PCT impact in support of AREVA fuel transition for Calvert Cliffs Unit 1 (ANP-2871) SBLOCA and resulted in an 8°F PCT impact to Calvert Cliffs Unit 1 and 2 (ANP-2834) RLBLOCA. No new assessments were applicable to Calvert Cliffs Unit 2 (ANP-2871) SBLOCA.

4. Prior LOCA Model Assessment

The 10 CFR 50.46 combined 30-day and annual report dated April 22, 2013 reported a new licensing basis PCT for Calvert Cliffs Unit 2 (ANP-3043) RLBLOCA applicable to once- and twice-burned fuel and a new error, respectively. The report changed the licensing basis to Calvert Cliffs Unit 2 RLBLOCA applicable to AREVA fuel to 1620°F PCT. The (ANP-2834) RLBLOCA analysis applicable to Notes 1 through 4 assumed fresh fuel was limiting and applied a statistical treatment to the multiplier on decay heat. The inclusion of the burnup

dependent RLBLOCA report satisfies the Technical Specification Appendix C license condition and allows for a full core of AREVA fuel in Calvert Cliffs Unit 2. The 10 CFR 50.46 report reported an error due to Cathcart-Pawel uncertainty implementation in RLBLOCA application resulting in a 0°F PCT impact. An error in the S-RELAP5 Sleicher-Rouse correlation used for predicting the heat transfer to single-phase vapor heat transfer resulted in an 8°F PCT to Calvert Cliffs Unit 2 RLBLOCA. No impacts reported for SBLOCA.

#### 5. Prior LOCA Model Assessment

The 10 CFR 50.46 combined 30-day and annual report dated March 20, 2014 reported a new licensing basis PCT for Calvert Cliffs Unit 1 (ANP-3043) RLBLOCA applicable to once- and twice-burned fuel and a new error, respectively. The report changed the licensing basis to Calvert Cliffs Unit 1 RLBLOCA applicable to AREVA fuel to 1620°F PCT. The (ANP-2834) RLBLOCA analysis applicable to Notes 1 through 4 assumed fresh fuel was limiting and applied a statistical treatment to the multiplier on decay heat. The inclusion of the burnup dependent RLBLOCA report satisfies the Technical Specification Appendix C license condition and allows for a full core of AREVA fuel in Calvert Cliffs Unit 1. The 10 CFR 50.46 report reported an error due to an issue with S-RELAP5 routine associated with the RODEX3a fuel rod model resulting in a 6°F PCT impact to RLBLOCA. The error in the S-RELAP5 Sleicher-Rouse correlation used for predicting the heat transfer to single-phase vapor heat transfer in combination with the error due to an issue with S-RELAP5 routine associated with the RODEX3A fuel rod model resulted in a 14 °F PCT impact. No impact reported for SBLOCA.

#### 6. Prior LOCA Model Assessment

The 10 CFR 50.46 30-day report dated April 23, 2014 reported an error in the correlation for vapor absorptivity use in S-RELAP5, applied outside of its intended range of applicability (no limit was imposed on the pressure at which the correlation was applied). The equation used for the absorption coefficient of vapor contains the term of the pressure which needs to be truncated in order to obtain the correct emissivity values for an optically thick steam. Correction of this error is expected to result in a 63°F PCT change to Calvert Cliffs Unit 1 and 2 SBLOCA. The estimated impact of this change on the RLBLOCA analysis calculated PCT is 0°F.

#### 7. Prior LOCA Model Assessment

The revised 10 CFR 50.46 report dated July 14, 2015 reported an error in the modal decomposition method which led to a detailed examination of the actual axial shapes that were produced by the modal decomposition procedure and it was observed that some of these resulting shapes were significantly different from the 24-node shape that was generated by PWR Core Engineering. These shapes exhibit a super-imposed oscillation created by the modal decomposition that leads to non-physical artificial local peaks and valleys in the shape. When such shapes are generated and used in the LOCA analyses they tend to shift the PCT both in the positive and negative direction depending on application. This led to the conclusion that in future application, the modal decomposition method will not

be used and a linear interpolation will be used for the mapping. The linear interpolation provides a significantly better fit for the axial shapes. This evaluation led to a 0°F PCT impact to Calvert Cliffs Unit 1 and 2 RLBLOCA analysis. This issue is not applicable to the SBLOCA analysis.

#### 8. Prior LOCA Model Assessment

The 10 CFR 50.46 report dated March 18, 2016 identified once-burned fuel, UO<sub>2</sub> and Gadolinia-bearing (GAD) rods, are generally modeled at a reduced peaking in comparison with the hot fresh UO<sub>2</sub> rod. The reduction is achieved by imposing a burnup-dependent multiplier, or cutback factor, specifying the radial peaking as a fraction of the hot rod radial peaking. A review indicated that cutback factor for once-burned Gad rods were instead applied as a fraction of the once-burned UO<sub>2</sub> rod resulting in the inadvertent once-burned GAD being modeled at a reduced power. This evaluation led to a 0°F PCT impact to Calvert Cliffs Unit 1 and 2 RLBLOCA analysis. This issue is not applicable to the SBLOCA analysis.

#### 9. Prior LOCA Model Assessment

The 10 CFR 50.46 report dated March 17, 2017 reported no model changes or errors for both the RLBLOCA and SBLOCA analyses.

#### 10. Prior LOCA Model Assessment

CR 2017-3565 identified an update to the M5<sup>®</sup> swelling and rupture mode (SRM) had the potential to impact Calvert Cliff's SBLOCA analysis.

M5<sup>®</sup> SRM is used in several of AREVA LOCA methodologies and since approval of the M5<sup>®</sup> SRM in the M5<sup>®</sup> Licensing Topical Report, BAW-10227, Rev. 1 (P)(A) by the NRC in the early 2000s, additional M5<sup>®</sup> cladding rupture test data was obtained. Following the same approach as the original model, an updated M5<sup>®</sup> SRM was developed to consider the updated test data. The model changes do not change the predicted occurrence or conditions at the time of rupture, but would impact the post-rupture cladding characteristics for certain rupture temperatures.

Calvert Cliffs Units 1 and 2 SBLOCA uses M5<sup>®</sup> SRM. The analyses of record rupture temperatures were less than the range of the model changes, and therefore a 0°F PCT estimate was assigned. The Calvert Cliffs Units 1 and 2 RLBLOCA analysis was performed with a LOCA methodology which did not use the M5<sup>®</sup> SRM and therefore is not affected.

#### 11. Prior LOCA Model Assessment

CR 2017-5630 identified an error in the S-RELAP5 calculations of oxidation due to high temperature metal-water reaction. In a LOCA event, the cladding can swell (and potentially rupture) due to the difference in pressure between the fuel and the system. As the clad radius increases, the thickness decreases. It was discovered that the S-RELAP5 oxidation

calculations used cold cladding dimensions and therefore, did not fully account for the swelling phenomena. The error can lead to an under-prediction of the oxidation and heat from the metal-water reaction.

Calvert Cliffs Units 1 and 2 SBLOCA analysis utilizes S-RELAP5 and it was determined that the estimated PCT effect is +6°F. The local oxidation and whole core hydrogen remain well within the 10 CFR 50.46 acceptance criteria with the correction. The Calvert Cliffs Units 1 and 2 RLBLOCA analysis was performed with a LOCA methodology which did not model swelling and therefore is not affected.

## 12. Prior LOCA Model Assessment

Calvert Cliffs Units 1 and 2 SBLOCA was re-analyzed using Evaluation Model EMF-2328(P)(A), Revision 0, Supplement 1(P)(A), Revision 0. The local oxidation and whole core hydrogen remain well within the 10 CFR 50.46 acceptance criteria. The analysis establishes an AOR PCT of 1648 °F. No errors in or changes to the EMF-2328(P)(A), Revision 0, Supplement 1(P)(A), Revision 0 analysis have been reported.

There were no errors or changes reported against RLBLOCA during this reporting period.

## 13. Current LOCA Model Assessment

There were no errors or changes reported against Calvert Cliffs Units 1 and 2 SBLOCA during this reporting period.

An error in the implementation of the Cathcart-Pawel correlation was discovered. The correlation is used for the calculation of metal-water reaction in the Framatome EMF-2103(P)(A) RLBLOCA methodologies. The correlation for the rate of oxide thickness was used instead of the correlation for the rate of total oxygen consumed. The correlation for the rate of total oxygen consumed is what is expected to be used for the 10 CFR 50.46 (b)(2) criterion. As compared to a total oxygen-based implementation, the use of the oxide-based implementation led to a more conservative prediction of the transient oxidation and heat released during the reaction. The additional heat from the reaction could have resulted in higher calculated values of the AOR peak clad temperature (PCT). For LBLOCA though, the difference in results between the two correlation implementations has a negligible impact on PCT. The PCT impact for the Calvert Cliffs Units 1 and 2 RLBLOCA analysis is 0°F.