UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

June 6, 2019

Mr. Joseph W. Shea, Vice President,
Nuclear Regulatory Affairs
and Support Services
Tennessee Valley Authority
1101 Market Street, LP 4A
Chattanooga, Tennessee 37402-2801

SUBJECT: BROWNS FERRY NUCLEAR PLANT, UNITS 1, 2, AND 3 – SUMMARY REPORT FOR THE AUDITS IN SUPPORT OF LICENSE AMENDMENT REQUEST FOR OPERATION IN THE EXPANDED MAXIMUM EXTENDED LOAD LINE LIMIT ANALYSIS PLUS OPERATING DOMAIN (EPID L-2018-LLA-0048)

Dear Mr. Shea:

By letter dated February 23, 2018, as supplemented by letters dated March 7, 2018 and July 23, 2018, Tennessee Valley Authority (TVA or the licensee) submitted a license amendment request (LAR) to Renewed Facility Operating License Nos. DPR-33, DPR-52, and DPR-68 for the Browns Ferry Nuclear Plant, Units 1, 2, and 3 (Browns Ferry). The proposed amendments would allow operation of Browns Ferry in the expanded Maximum Extended Load Line Limit Analysis Plus (MELLLA+) operating domain.

To support its safety evaluations, the Nuclear Regulatory Commission (NRC) staff determined the need for a regulatory audit to be conducted in accordance with the Office of Nuclear Reactor Regulation Office Instruction LIC 111, "Regulatory Audits," for the staff to gain a better understanding of the licensee's approach, calculations, and other aspects of the MELLLA+ LAR. The audit plan to support the review of this LAR was issued on September 27, 2018.

The NRC staff conducted two audits to support this review. The first audit (Excel Audit) was held at Excel Services Corporation in Rockville, MD, from October 9 to October 11, 2018. The second audit (Simulator Audit) was held at Browns Ferry in Athens, AL on February 27, 2019. The list of attendees for these audits are provided in Enclosures 1 and 2.

Enclosure 3 transmitted herewith contains Sensitive Unclassified Non-Safeguard Information. When separated from Enclosure 3, this document is decontrolled.

The NRC staff has documented the observations, discussions, and conclusions from the audits in the audit report in Enclosure 3. The staff has determined that its audit summary in Enclosure 3 contains proprietary information pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR) Section 2.390, "Public inspections, exemptions, requests for withholding." Accordingly, the NRC staff has prepared a redacted, nonproprietary version (Enclosure 4). However, the NRC staff will delay placing the nonproprietary audit report in the public document room for a period of 10 working days from the date of this letter to allow TVA to comment on any proprietary aspects. If you believe that any information in Enclosure 4 is proprietary, please identify such information line by line and define the basis pursuant to the criteria of 10 CFR 2.390. After 10 working days, the nonproprietary audit report will be made publicly available. No regulatory decisions were made during this audit.

Based on the discussions with the TVA staff and review of the documents during the Excel Audit, the NRC staff developed requests for additional information (RAIs) and issued the official RAIs by letters dated November 20, and December 6, 2018. The licensee's responses to the RAIs were submitted to the NRC by letters dated December 4, 2018; December 13, 2018; December 14, 2018; January 16, 2019 (2 letters); and January 25, 2019.

As the result of the Simulator Audit, the licensee submitted Supplement 8 dated March 13, 2019, that provided information related to an issued NRC Green finding for the failure of 4 of 15 Browns Ferry operating crews during their 2018 annual simulator scenario examinations and the impact on initial operator actions for an anticipated transient without SCRAM.

If you have any questions, please contact me at (301) 415-1447 or Farideh.Saba@nrc.gov.

Sincerely,

/RA/

Farideh E. Saba, Senior Project Manager
Plant Licensing II-2
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket Nos. 50-259, 50-260, and 50-296

Enclosures:
1. List of Attendees for Excel Audit
2. List of Attendees for Simulator Audit
3. Summary Report for Audit (Proprietary)
4. Summary Report for Audit (Non-Proprietary)

cc: w/ Enclosures 1, 2, and 4: Listserv **(10 days after issuance of the audit report to the licensee)**

LIST OF ATTENDEES

OCTOBER 9 - 11, 2018, AUDIT OF TENNESSEE VALLEY AUTHORITY

BROWNS FERRY NUCLEAR PLANT, UNITS 1, 2, AND 3

EXCEL AUDIT

ASSOCIATED WITH MELLLA+

LICENSE AMENDMENT REQUEST

Name	**Affiliation**	**10/09**	**10/10**	**10/11**	**Exit 10/11**
Joshua Borromeo	NRC	x	x	x	x
Diana Woodyatt	NRC	x	x	x	x
Mathew Panicker	NRC	x	x	x	x
John Hughey	NRC	x	x	x	x
Farideh Saba	NRC	x	x	x	x
Ahsan Sallman	NRC		x		
Ashley Smith	NRC		x[1]		
Undine Shoop	NRC				x
Aaron Wysocki	ORNL/NRC	x	x	x	x
Pete Donahue	TVA	x	x	x	x
Daniel Green	TVA	x	x	x	x
William Baker	TVA	x	x	x	x
Michael Dick	TVA	x	x	x	x
Gordon Williams	TVA	x	x	x	
Denny Campbell	TVA	x	x	x	x
Bill Bird	TVA		x	x	x
Barry Myers	TVA	x	x	x	x
Greg Storey	TVA	x	x	x	x
Alan Meginnis	Framatome	x[1 and 2]		x	x
David McBurney	Framatome	x[1 and 2]		x	x

1 By the phone
2 Partially

Name	Affiliation	10/09	10/10	10/11	Exit 10/11
Dan Tinkler	Framatome	x[1 and 2]		x[1]	
Scott Tylinki	Framatome			x[1]	
Earl Riley	Framatome			x[1]	
Scott Franz	Framatome			x[1]	
Ralph Grummer	Framatome			x[1]	
Gerald Kvaall	GNF	x	x		
Larry King	GEH	x	x		
Michael Cook	GNF	x	x		
Tyler Schwitzer	GEH		x		

1 By the phone
2 Partially

LIST OF ATTENDEES

FEBRUARY 27, 2019, AUDIT OF TENNESSEE VALLEY AUTHORITY

BROWNS FERRY NUCLEAR PLANT, UNITS 1, 2, AND 3

SIMULATOR AUDIT

ASSOCIATED WITH MELLLA+

LICENSE AMENDMENT REQUEST

Name	**Affiliation**	**02/27**	**Notes**
Joshua Borromeo	NRC	x	
Diana Woodyatt	NRC	x	
John Hughey	NRC	x	
Farideh Saba	NRC	x	
Peter Yarsky	NRC	x	
Aaron Wysocki	ORNL/NRC	x	
Jennifer Whitman	NRC	x[1 and 2]	Introduction
Thomas Stephen	NRC	x	
Pete Donahue	TVA	x	
Daniel Green	TVA	x	
William Baker	TVA	x	
Michael Dick	TVA	x	
Tracy Orf	TVA	x	
Denny Campbell	TVA	x[2]	Discussion session
Werner Paulhardt	TVA	x	
Barry Myers	TVA	x	
Ronald King	TVA	x	
Chris Vaughn	TVA	x	
Monte McAndrew	TVA	x	

[1] On the phone
[2] Partially

ENCLOSURE 4
(NON-PROPRIETARY)

REGULATORY AUDIT REPORT FOR

TENNESSEE VALLEY AUTHORITY

BROWNS FERRY PLANT UNITS 1, 2, AND 3

REQUEST FOR OPERATION IN THE EXPANDED MAXIMUM EXTENDED LOAD LINE LIMIT ANALYSIS PLUS OPERATING DOMAIN

This document contains proprietary information pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR) Section 2.390.

Proprietary information is identified by bolded text enclosed within double brackets as shown here [[Example of proprietary information]].

REGULATORY AUDIT REPORT FOR

TENNESSEE VALLEY AUTHORITY

BROWNS FERRY PLANT UNITS 1, 2, AND 3

REQUEST FOR OPERATION IN THE EXPANDED MAXIMUM EXTENDED LOAD LINE LIMIT ANALYSIS PLUS OPERATING DOMAIN

1.0 INTRODUCTION

By letter dated February 23, 2018 (Reference 1), as supplemented by letters dated March 7, 2018 (Reference 2), and July 23, 2018 (Reference 3), Tennessee Valley Authority (TVA, the licensee) submitted a license amendment request (LAR) to Renewed Facility Operating License Nos. DPR-33, DPR-52, and DPR-68 for the Browns Ferry Nuclear Plant Units 1, 2, and 3 (Browns Ferry or BFN). The proposed amendments would allow operation of Browns Ferry in the expanded Maximum Extended Load Line Limit Analysis Plus (MELLLA+) operating domain.

The Nuclear Regulatory Commission (NRC) staff conducted two audits to support review of the MELLLA+ LAR. The first audit was held at Excel Services Corporation in Rockville, MD from October 9 to October 11, 2018. The second audit was held at Browns Ferry in Athens, AL on February 27, 2019.

During the audit at Excel Services (referred to as the Excel Audit in this audit report), the licensee presented several different technical areas followed by in-depth discussion and examination of calculation notebooks by the NRC staff. The approach used by the licensee for this LAR was similar, in many respects, to the approach used in the Brunswick Steam Electric Plant (BSEP) MELLLA+ LAR (Reference 4), which was previously reviewed by the staff. Due to this significant overlap, the technical discussions during the audit focused on the differences in the technical approaches used in these two submittals. No regulatory decisions were made by the staff during the audit; however, several preliminary draft requests for additional information (RAIs) were developed based on the information discussed during the audit.

During the second audit at Browns Ferry (referred to as the Simulator Audit in this audit report), the NRC staff observed the plant operators performing simulator exercises of the anticipated transient without SCRAM (ATWS) event. The staff focused on what operator actions were completed to mitigate the event and the time it took to perform those actions. Specific operator action times are necessary to mitigate the ATWS event. In addition, the staff sought to understand a recent Green Finding (Reference 5) related to operator training. It was necessary for the staff to determine if the finding would have any impact regarding the operator actions to mitigate ATWS events. Finally, the staff wanted to understand how uncertainties from the lattice physics and core simulator code were developed and then used in the safety limit minimum critical power ratio (SLMCPR) methodology.

The following NRC staff and contractors participated in both the Excel Audit and Simulator Audit:

- Josh Borromeo, Reactor Systems Engineer, Office of Nuclear Reactor Regulation (NRR)
- Diana Woodyatt, Reactor Systems Engineer, NRR
- Aaron Wysocki, Consultant/Contractor, Oak Ridge National Laboratory
- John Hughey, Human Factors Engineer, NRR
- Farideh Saba, Senior Project Manager, NRR

The following NRC staff participated in the Excel Audit only:

- Mathew Panicker, Reactor Systems Engineer, NRR
- Ashley Smith, Reactor Systems Engineer, NRR
- Ahsan Sallman, Senior Reactor Systems Engineer, NRR

The following NRC staff participated in the Simulator Audit only:

- Peter Yarsky, Senior Reactor Engineer, Office of Research

This audit report contains the NRC staff's observations and conclusions from the audits. No regulatory decisions were made during this audit.

2.0 EXCEL AUDIT

The primary discussion topics for each day of the audit were as follows:

- October 9, 2018: General Electric Hitachi (GEH) methods applicability to ATRIUM 10XM fuel, and ATWS-I.
- October 10, 2018: Detect and Suppress Solution – Confirmation Density (DSS-CD) and ATWS.
- October 11, 2018: Loss-of-coolant-accident (LOCA), anticipated operational occurrences (AOOs), and Framatome methods.

TVA staff members were in attendance throughout the audit. Based on the content of the discussions held each day, GEH staff members were in attendance on October 9 and October 10, 2018, and Framatome staff members were in attendance on October 11, 2018.

Based on the discussions with the TVA staff and review of the documents during the Excel Audit, the NRC staff developed RAIs, which were issued by letters dated November 20, 2018 (Reference 6), and December 6, 2018 (Reference 7). The licensee's responses to the RAIs were submitted to the NRC by letters dated December 13, 2018 (Reference 8); December 14, 2018 (Reference 9), January 16, 2019 (2 letters (Reference 10) and (Reference 11)), and January 25, 2019 (Reference 12).

2.1 GEH Methods Applicability ATRIUM 10XM Fuel

All three Browns Ferry units will operate with a full core of ATRIUM 10XM fuel during MELLLA+ operation, with the possibility of some legacy ATRIUM-10 fuel in some non-limiting peripheral locations during the first MELLLA+ cycle. The approach used to represent ATRIUM 10XM fuel in Browns Ferry with GEH methods was essentially an extension of the modeling bases used for ATRIUM-10 fuel, similar to the approach used in the BSEP MELLLA+ LAR. GEH methods were used in the Browns Ferry MELLLA+ for the DSS-CD, ATWS, and ATWS-I analyses.

The ATRIUM 10XM fuel geometry and materials were explicitly modeled by GEH based on inputs from Framatome. Documentation on these inputs was reviewed by the staff during the audit. To limit the ATRIUM 10XM fuel performance information that needed to be passed from Framatome to GEH, the ATRIUM-10 calculation bases (used by GEH for previous applications) were applied to ATRIUM 10XM fuel by increasing the applicable uncertainties and obtaining confirmation from Framatome that the applied uncertainty ranges are appropriate for ATRIUM 10XM fuel relative to ATRIUM-10 fuel.

During the audit, the NRC staff determined that, with very limited exceptions, Browns Ferry used an identical approach to represent ATRIUM 10XM as was used for BSEP MELLLA+. Operating conditions and ATWS/ATWS-I event progression for Browns Ferry and BSEP are relatively similar, and the staff did not identify any aspects of the Browns Ferry plant or MELLLA+ application that would invalidate this GEH ATRIUM 10XM modeling approach or make it inapplicable for use in the Browns Ferry MELLLA+. The same sensitivity parameters and ranges were applied in Browns Ferry and BSEP, with the exception that of the **[[ ]]**. At the audit, the staff determined that this change in sensitivity range was a result of plant-specific core loading and operating condition differences that led to a change in the largest difference in gap conductance between ATRIUM 10XM and ATRIUM-10 across the range of linear heat rate and burnup considered. The staff verified that the actual method of calculating these ranges in Browns Ferry was identical to that used for BSEP, and that these differences in **[[ ]]** were understandable and not unexpected.

Two notable differences were identified in the GEH ATRIUM 10XM modeling approach relative to the approach for BSEP: a difference in determining ISCOR pressure loss coefficients, and a difference in applying R-factors for the GEXL critical quality correlation. These differences are described in the following paragraphs.

GEH developed the pressure loss coefficients for the ISCOR model based on Framatome-supplied XCOBRA thermal hydraulic losses and flow rates for ATRIUM 10XM, rather than the licensee (Duke, in the case of BSEP) developing the loss coefficients. During the audit, the NRC staff reviewed data provided by Framatome in the following documents:

- FS1-0029998, "Browns Ferry EPU [Extended Power Uprate] MELLLA+ LAR Thermal Hydraulic Data"
- FS1-0029795, "ATRIUM 10XM Data for Browns Ferry MELLLA+ LAR Support"

During the audit the following documents that describe GEH's thermal hydraulic loss coefficient determination process and application to Browns Ferry MELLLA+:

- TDP-0243 Revision 0, "Generation of Steady-State ISCOR Thermal-Hydraulic Model Coefficients for Alternate Vendor Fuel"
- 004N2200 Revision 0, "Brown Ferry ATRIUM 10XM ISCOR Model for MPLUS LAR Support"

The process used by Duke Energy for BSEP differed from the process used by GEH for Browns Ferry. In particular, GEH used a previously-defined methodology (TDP-0243 Revision 0) to determine optimum ISCOR loss coefficients to match other-vendor thermal hydraulic data. This process was not used by Duke in the BSEP MELLLA+ application.

However, despite differences in the specific approach used to develop the ISCOR thermal hydraulic inputs, the agreement between Framatome and GEH steady-state thermal hydraulic and neutronic calculations for an equilibrium Browns Ferry MELLLA+ cycle was on par with what was observed for similar calculations for BSEP MELLLA+. No deficiencies or unexpected differences were seen between the two vendors' neutronic and thermal hydraulic cycle calculations for Browns Ferry MELLLA+.

Detailed pin-dependent R-factors were calculated by Framatome and supplied to GEH for the ATWS-I calculations. However, GEH applied a single, uniform R-factor value across all pins and bundles, due to the significant effort (with little or no benefit in accuracy) that would be required to apply the pin-dependent values to the TRACG model. This conclusion was based on the lack of effect on peak cladding temperature (PCT) that was observed in the GEXL sensitivity study for ATWS-I. Instead of pin-dependent R-factors, GEH applied an R-factor of **[[ ]]** to all pins, which is approximately the average R-factor across all ATRIUM 10XM pins in the R-factor map supplied by Framatome. The BSEP MELLLA+ LAR applied a constant R-factor to all pins as well, but the value chosen for BSEP was **[[ ]]**, which was lower than any R-factor supplied by Framatome and provided conservatism in the direction that GEH found to give higher PCT (based on a GEXL sensitivity study for ATWS-I).

2.2 ATWS-I

During the audit, the licensee presented detailed ATWS-I results using TRACG, including the impact of individual fuel parameter sensitivities on the calculated results, comparison of the dual recirculation pump trip (2RPT) and turbine trip with bypass (TTWBP) event results, effect of the use of the **[[ ]]**, and an additional detailed breakdown of results demonstrating the impact of the fuel parameter sensitivities on timing effects as well as "fully developed" limit cycle oscillation behavior.

By examining the effect of changing individual fuel parameters, it was observed that each parameter affected the various aspects of the oscillations – oscillation onset time, oscillation growth rate, time of first dryout, time of failure to rewet – in different ways. For example, the **[[ ]]** did not affect the oscillation onset time or growth rate (as expected) but affected the time of first dryout and had some effect on the behavior thereafter. However, while certain parameters may affect some aspects more than others, most of the parameters generally appeared to have some degree of impact on *all* aspects of the oscillations. For example, parameter variations that led to earlier and faster oscillation growth also tended to give earlier initial dryout, earlier failure-to-rewet, and larger increases in PCT during these oscillation phases.

The NRC staff examined the TTWBP calculations that were provided during the audit (but not in the LAR), including the additional sensitivities on fuel parameters, **[[ ]]**. These cases demonstrated that the **[[ ]]** in terms of PCT, for all variations of these modeling *assumptions that were considered in* the LAR. This information will be requested in an RAI and will assist the staff in ensuring that the most limiting postulated ATWS-I event was considered regardless of modeling assumptions.

After its initial review of the LAR, the staff noted that the fuel parameter sensitivities accounted for [[ ]] in PCT relative to the nominal fuel parameter case when the [[ ]] was used, but a [[ ]] in PCT when [[ ]] was used. To better understand the reason for this difference, the NRC staff examined an additional breakdown of results given by the licensee that presented cladding temperature results [[

]] The NRC staff indicated that it will request this information in an RAI to support the staff's evaluations by allowing the staff to better understand the role of the fuel parameter sensitivities in affecting PCT under various calculation scenarios.

The staff also discussed with the licensee the possibility of issuing an additional RAI to provide an additional quantification of the degree of "margin" that is present in terms of the fuel parameter values with respect to reaching 2200 °F during the 2RPT ATWS-I event with [[ ]]. Considering that [[

]].

2.3 DSS-CD

The approach used for implementing DSS-CD in Browns Ferry MELLLA+ is essentially identical to the approach for BSEP MELLLA+. The staff determined that the minimum critical power ratio (MCPR) margin with DSS-CD in Browns Ferry MELLLA+ [[ ]] for BSEP MELLLA+. Partly because the stability safety margin is [[ ]] BSEP MELLLA+, the fuel parameter sensitivity studies were not performed for Browns Ferry MELLLA+ for the DSS-CD confirmatory analyses.

However, the NRC staff notes that the applicability extension procedure to confirm the acceptability of DSS-CD for [[

]]. The NRC staff reviewed the DSS-CD licensing topical report (LTR) and found no provision in that

LTR for allowing use of DSS-CD for fuel for that **[[** **]]**. The NRC staff indicated during the audit that they intend to issue an RAI to address the acceptability of this aspect of the DSS-CD implementation.

The staff also focused on the proposed increase of the DSS-CD **[[** **]]**. This is similar to the approach used in the BSEP MELLLA+ LAR, in that **[[** **]]**. The staff indicated during the audit that they intend to issue an RAI to address this issue.

Additionally, the licensee showed that the **[[** **]]**. The staff indicated during the audit that they intend to issue an RAI to address this issue as well.

2.4 Anticipated Operational Occurrences

The licensee presented the limiting critical power ratio (CPR) AOO results for the MELLLA+ corner of the power to flow map (i.e., 100 percent power and 85 percent flow) and compared them to EPU results (100 percent power and 105 percent flow). While the results at the MELLLA+ conditions were less limiting than EPU, there was no indication that the MELLLA+ results were unrealistic. The staff and licensee discussed the Browns Ferry reload process and how the MELLLA+ statepoint were considered. The staff gained an understanding of the steps taken by the licensee to ensure that the limiting CPR is identified including the consideration of AOOs in MELLLA+.

2.5 Loss-of-Coolant Accident

Since the overall PCT result of the LOCA analysis in MELLLA+ was relatively high (>2000 ºF), the staff wanted to understand the physical reason why the PCT results were different at various MELLLA+ statepoints. The licensee described that MELLLA+ did not have a strong impact on the results since the primary contributor in the LOCA analysis is decay heat (that is not impacted by MELLLA+). The licensee discussed that, since there is not a clear conservative direction when comparing MELLLA+ conditions (i.e., 100 percent power and 85 percent flow) and EPU conditions (i.e., 100 percent power and 100 percent flow), that both these statepoints are analyzed. This requirement is also in GEH MELLLA+ LTR. In addition to the minimum requirements in the GEH MELLLA+ LTR, the licensee also provided an analysis of a mid-point on the 100 percent rod line (i.e., 100 percent power and **[[** **]]** flow) to ensure that the limiting result statepoint was captured. These results were less limiting than the results provided in the submittal, thus provided the NRC staff confidence that the limiting LOCA statepoints were captured.

2.6 Framatome Methods Review

As discussed in the Introduction Section, the Browns Ferry approach was very similar to the Brunswick MELLLA+ approach. Therefore, the staff focused on any differences in justification for Framatome methods applicability in the MELLLA+ operating domain compared to Brunswick. The licensee discussed that there were very minimal differences in justification. The staff reviewed calculation notebooks, identified in Section 2.8 of this report, to support the staff's understanding of how the methods were justified for Browns Ferry MELLLA+.

2.7 Operator Actions

The licensee discussed the operator actions to mitigate the ATWS-I event with the NRC staff. The licensee provided tested operator action times to validate the 120-second operator action time for the TTWBP ATWS-I event. TVA also provided validation times for 180-second 2RPT ATWS-I response times and discussed the need for validation of the 60 seconds to identify ATWS conditions. Additionally, TVA discussed how such short operator response times (relative to NRC staff experience) were achieved, which included:

- Having abnormal operating instructions (AOI) hard cards; emergency operating instruction (EOI) flow chart sheets and Emergency Operating Procedures (licensee provided samples) in the control room;
- Institute of Nuclear Power Operations (INPO) inspection of Browns Ferry in 2016 resulted in an INPO Area for Improvement (AFI) issued to Browns Ferry regarding crew response to ATWS. At the same time, Browns Ferry began working on implementing EPU. Thus, TVA established a team to support EPU implementation that included resolution of the AFI.
- Built EPU model in the simulator;
- Started validating simulator model with EPU team;
- Went into simulator with current operating limits to validate operator actions;
- Developed EOIs and AOI hard cards: standard actions when an ATWS has been identified by the operators up to standby liquid control initiation;
- Reorganized flow of actions for operator response to an ATWS;

- No decision points required after ATWS identified – operator simply follows the AOI hard card steps;
- Applied this process to preparation for MELLLA+;
- The hard card set of steps is the only way an ATWS is responded to;
- The operators just follow the steps on the EOI charts and AOI hard cards – no deviations.

2.8 Documents Review

The following list provides the documents reviewed during the Excel Audit:

- FS1-0029998, "Browns Ferry EPU MELLLA+ LAR Thermal Hydraulic Data"
- FS1-0029795, "ATRIUM 10XM Data for Browns Ferry MELLLA+ LAR Support"
- TDP-0243 Revision 0 "Generation of Steady-State ISCOR Thermal-Hydraulic Model Coefficients for Alternate Vendor Fuel"
- 004N2200 Revision 0 "Browns Ferry ATRIUM 10XM ISCOR Model for MPLUS LAR Support"
- FSI-0029307, Revision 1.0, "Browns Ferry EPU MELLLA+ AMSAR [AREVA MELLLA+ Safety Analysis Report] – SLMCPR Analysis"
- 32-9137288-000, "CASMO-4/MICROBURN-B2 Uncertainty Analysis Statepoint Information and Plots"
- FS1-003-0394, Revision 1.0, "GEXL Correlation for ATRIUM 10XM Fuel for Browns Ferry MELLLA+ ATWS-I Analysis"
- GEH-PGN-MPLUS-035, "Transmittal of GEXL97 Correlation for Atrium 10 Fuel for Brunswick Nuclear Station MELLLA+ Application"
- FS1-0029303 Revision 1.0, "Browns Ferry EPU MELLLA+ Compatibility Analysis"
- 32-9173396-000, "Browns Ferry ATRIUM 10XM Characterization"
- FS1-0029828 Revision 1.0, "Browns Ferry Unit 3 ATRIUM 10XM EPU MELLLA+ Equilibrium Cycle RODEX4 AUTOBOW Run"
- FS1-0029706 Revision 1.0, "Browns Ferry Unit 3 ATRIUM 10XM EPU MELLLA+ Equilibrium Cycle SAFLIM3D AUTOBOW Run"
- FS1-0031484 Revision 4.0, "Support for Uncertainty Evaluation in High P/F Conditions"
- FS1-0030312 Revision 2.0, "Fuel Rod Thermal-Mechanical Analysis, Browns Ferry EPU/MELLLA+ Equilibrium Cycle-ATRIUM 10XM" - MP

3.0 SIMULATOR AUDIT

3.1 Simulator Tour

Prior to the simulator exercises, the staff toured the BFN Unit 3 simulator. The purpose of the tour was for the NRC staff to become familiarized with the control room layout and the actions the operators would be taking during the simulator exercises. During this tour, the staff asked questions about the plant and different actions that affect the ATWS event progression.

The staff discussed the performance of the feedwater system during ATWS as well as main steam isolation valve bypass. The feedwater system discussion informed the staff of the appropriate modeling to use for confirmatory calculations. The licensee explained that the bypass in Units 1 and 2 is achieved through key locks in the main control room. However, at the current time, the process is different for Unit 3. In Unit 3 it is necessary to apply jumper wires to bypass the main steam isolation valve (MSIV) closure trip; however, the licensee clarified that they are implementing a design change to make the Unit 3 design the same as the design for Units 1 and 2. The licensee staff showed the NRC staff where the planned changes are marked on the Unit 3 simulator control panels.

As the result of the Simulator Audit, the licensee submitted Supplement 8 to this LAR, dated March 13, 2019 (Reference 13), that provided information related to an NRC Green finding issued for the failure of 4 of 15 Browns Ferry operating crews during their 2018 annual simulator scenario examinations and the impact on initial operator actions for an anticipated transient without SCRAM.

3.2 Simulator Exercises

The staff observed three exercises in the BFN Unit 3 simulator for three different ATWS scenarios. The first event is initiated by a TTWBP available with simulated thermal hydraulic instability. The second event is a dual recirculation pump trip (2RPT), but this event is initiated following a distractor related to the balance of plant. The third event is an isolation ATWS event initiated by spurious closure of all MSIVs. All events were initiated from the MELLLA+ high power (100 percent), low flow (85 percent recirculation drive flow) point on the power/flow map.

In addition, the NRC staff also observed operating crew tabletop exercises involving TSs and plant procedures regarding OPRM upscale function inoperable (transfer to automatic backup stability protection) and loss of OPRM upscale function and automatic backup stability protection.

The measured ATWS operator action times during the February 27, 2019, simulator observations are presented in Table 1 below:

TABLE 1: Measured ATWS Operator Action Response Times

Scenario	Required Operator Action	Operator Action Time (seconds)	Required Response Time (seconds)
TTWBP (Scenario 1)	RWL* Reduction	26.25	120
	SLC Injection	31.25	120
2RPT w/Distractor (Scenario 2)	RWL Reduction	29.0	180
	SLC Injection	33.0	180
MSIV Closure (Scenario 3)	SLC Injection	30.7	120
	SPC** Initiation	336.95	660

* Reactor Water Level
** Suppression Pool Cooling

<u>TTWBP</u>

The staff observed the operator response in the simulator exercise to time the critical operator actions to lower reactor water level and to inject boron through the SLC system. Operators acted to control level in 26.25 seconds following the SCRAM signal and they acted to initiate SLC system injection in 31.25 seconds. These values were taken from the simulator log and were consistent with the NRC staff's observations during the exercise.

<u>2RPT</u>

The 2RPT simulation began with a separate event that was intended as a "distractor" before the unrelated 2RPT occurred. The primary purpose of including the distractor in the simulation was to reduce the likelihood that the operators "expected" an ATWS to occur during the simulated scenario, which may provide further insight into the operators' ability to respond to such an event during plant operation.

In this simulation, 29 seconds and 33 seconds, respectively, elapsed from the time of the 2RPT until the operators commenced water level reduction and initiated SLC. These values were taken from the simulator log and were consistent with the NRC staff's observations during the exercise. The staff also observed the exercise until the downcomer water level was stabilized.

<u>MSIV Closure</u>

The purpose of the MSIV closure was to observe the operators responding to a ATWS-depressurization event. In this event, SLC was initiated 31 seconds after the SCRAM attempt, well within the required 120 seconds action time. The suppression pool temperature rose following depressurization of the vessel, leading the operators to initiate suppression pool cooling (SPC) 337 seconds after the SCRAM, below the 660 seconds required residual heat removal SPC initiation time. The simulation was continued until all available SPC was in service (618 seconds after SCRAM) and operators began to increase the water level with reactor core isolation cooling and high-pressure coolant injection after hot shutdown boron weight (HSBW) was achieved, approximately 720 seconds after SCRAM. After this time, the simulation was ended.

Note that one of the four operating crew failures during annual requalification, as discussed below, related to the Senior Reactor Operator erroneously injecting coolant to the vessel prior to HSBW being achieved. During the Simulator Audit Scenario 3 exercise, the NRC staff observed that the operating crew successfully waited until after HSBW was achieved before taking action to raise the water level, such that the same failure resulting in the previous operating crew failure did not occur.

3.3 Green Finding Related to Operator Training

During the technical presentation, the licensee discussed the Browns Ferry Integrated Inspection Report, dated January 31, 2019 (Reference 14), Green inspection finding regarding a high crew failure rate during annual requalification wherein 4 of 15 operating crews failed the 5th operating cycle annual simulator scenario examinations. The licensee provided background information, corrective actions and subsequent validations of performance for the operating crews associated with the simulator exam failures. The NRC staff requested that the licensee submit this information, as a supplement to the LAR, to the NRC on the docket.

3.4 Uncertainties in the SLMCPR Methodology

During the Simulator Audit, the licensee provided a technical presentation on the components of the power distribution uncertainties that feed SLMCPR calculation. This proprietary presentation contained information from the NRC-approved CASMO-4/MICROBURN-B2 topical report (EMF-2158(P)(A), Revision 0). In particular, the staff was able to gain an understanding how the traversing-incore-probe predicted uncertainties were included in the development of the overall power distribution uncertainty that is included in the SLMCPR calculation. All the information presented and provided is contained in NRC-approved topical reports.

3.5 TRACG ATWS-I TTWBP Feedwater Pump Assumptions

During the Simulator Audit Scenario 1 exercise, the NRC staff observed that the feedwater pumps continued to operate and provide feedwater injection to the vessel following the turbine trip, even with a SCRAM, until operator actions were performed to terminate feedwater flow. At the NRC staff's request, the licensee clarified that feedwater flow continues after the turbine trip and is controlled automatically, with no operator intervention required for this to occur.

During the audit, the NRC staff and the licensee participated in a call with GEH, during which GEH confirmed that the ATWS-I TTWBP analyses performed by GEH correctly modeled the feedwater flow as continuing rather than dropping to zero after loss of the driving steam from the turbine. This confirmed that the GEH TTWBP analyses modeled the feedwater flow rate appropriately during the event and did not introduce a nonconservatism associated with early water level reduction and oscillation suppression that would have been caused by an erroneous assumption of loss of feedwater flow after the turbine trip.

This information improved the TRACE model to achieve better consistency with the expected plant and operator performance at Browns Ferry, and also confirmed that the TRACG modeling assumptions were consistent with the Browns Ferry plant and procedures.

4.0 REFERENCES

1 TVA letter to U.S. NRC, "Proposed Technical Specifications (TS) Change TS-510 – Request for License Amendments – Maximum Extended Load Line Limit Analysis Plus," dated February 23, 2018 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML18079B140).

2 TVA letter to U.S. NRC, "Proposed Technical Specifications (TS) Change TS-510 – Request for License Amendments – Maximum Extended Load Line Limit Analysis Plus, Supplement 1," dated March 7, 2018 (ADAMS Accession No. ML18067A495).

3 TVA letter to U.S. NRC, "Proposed Technical Specifications (TS) Change TS-510 – Request for License Amendments – Maximum Extended Load Line Limit Analysis Plus - Supplement 2, Operator Training Results," dated July 23, 2018 (ADAMS Accession No. ML18205A498).

4 Duke Energy letter to U.S. NRC, "Brunswick Steam Electric Plant, Unit Nos. 1 and 2 Renewed Facility Operating License Nos. DPR-71 and DPR-62 Docket Nos. 50-325 and 50-324 Request for License Amendment Regarding Core Flow Operating Range Expansion," dated September 6, 2016 (ADAMS Package Accession No. ML16257A418).

5 NRC Inspection Report, "Browns Ferry Nuclear Plant – NRC Integrated Inspection Report 05000259/2018004, 05000260/2018004, and 05000296/2018004," dated January 31, 2019 (ADAMS Accession No. ML19031C915).

6 NRC letter to TVA, "Browns Ferry Nuclear Plant, Units 1, 2, and 3 - Request for Additional Information Regarding Maximum Extended Load Line Limit Plus License Amendment Request (EPID L-2018-LLA-0048)," dated November 20, 2018 (ADAMS Accession No. ML18317A164).

7 NRC letter to TVA, "Browns Ferry Nuclear Plant, Units 1, 2, and 3 - Request for Additional Information Regarding Maximum Extended Load Line Limit Plus License Amendment Request (EPID L-2018-LLA-0048)," dated December 6, 2018 (ADAMS Accession No. ML18331A544).

8 TVA letter to U.S. NRC, "Proposed Technical Specifications (TS) Change TS-510 - Request for License Amendments - Maximum Extended Load Line Limit Analysis Plus - Supplement 4, Response to Request for Additional Information," dated December 13, 2018 (ADAMS Accession No. ML18347B381).

9 TVA letter to U.S. NRC, "Proposed Technical Specifications (TS) Change TS-510 - Request for License Amendments - Maximum Extended Load Line Limit Analysis Plus - Supplement 3, Responses to Requests for Additional Information," dated December 14, 2018 (ADAMS Accession No. ML18348B156).

10 TVA letter to U.S. NRC, "Proposed Technical Specifications (TS) Change TS-510 - Request for License Amendments - Maximum Extended Load Line Limit Analysis Plus - Supplement 5, Response to Requests for Additional Information," dated January 16, 2019 (ADAMS Accession No. ML19016A429).

11 TVA letter to U.S. NRC, "Proposed Technical Specifications (TS) Change TS-510 - Request for License Amendments - Maximum Extended Load Line Limit Analysis Plus - Supplement 6, Additional Operator Training Results," dated January 16, 2019 (ADAMS Accession No. ML19016A435).

12 TVA letter to U.S. NRC, "Proposed Technical Specifications (TS) Change TS-510 - Request for License Amendments - Maximum Extended Load Line Limit Analysis Plus - Supplement 7, Response to Requests for Additional Information," dated January 25, 2019 (ADAMS Accession No. ML19025A204).

13 TVA letter to U.S. NRC, "Proposed Technical Specifications (TS) Change TS 510 - Request for License Amendments - Maximum Extended Load Line Limit Analysis Plus - Supplement 8, Additional Operator Training Information," dated March 13, 2019 (ADAMS Accession No. ML19072A122).

14 The NRC Inspection Report, "Browns Ferry Nuclear Plant - NRC Integrated Inspection Report 05000259/2018004, 05000260/2018004, and 05000296/2018004," January 19, 2019 (ADAMS Accession No. ML19031C915).

SUBJECT: BROWNS FERRY NUCLEAR PLANT, UNITS 1, 2, AND 3 – SUMMARY REPORT FOR THE AUDITS IN SUPPORT OF LICENSE AMENDMENT REQUEST FOR OPERATION IN THE EXPANDED MAXIMUM EXTENDED LOAD LINE LIMIT ANALYSIS PLUS OPERATING DOMAIN (EPID L-2018-LLA-0048) DATED JUNE 6, 2019

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