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AREVA

Browns Ferry Unit 1 Cycle 12 Reload Analysis

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Nature of Changes

Item	Section(s) or Page(s)	Description and Justification
1.	All	This is the initial release.

Contents

Tables

Figures

Nomenclature

2PT	two pump trip
AOT	abnormal operational transient
APLHGR	average planar linear heat generation rate
ARO	all control rods out
ASME	American Society of Mechanical Engineers
AST	alternate source term
ATWS	anticipated transient without scram
ATWS-RPT	anticipated transient without scram recirculation pump trip
BFE1-12	Browns Ferry Unit 1 Cycle 12
BLEU	blended low enriched uranium
BOC	beginning-of-cycle
BPWS	banked position withdrawal sequence
BSP	backup stability protection
BWR	boiling water reactor
BWROG	Boiling Water Reactor Owners Group
CFR	Code of Federal Regulations
COLR	core operating limits report
CPR	critical power ratio
CRDA	control rod drop accident
CRWE	control rod withdrawal error
DIVOM	delta-over-initial CPR versus oscillation magnitude
EFPD	effective full-power days
EFPH	effective full-power hours
EOC	end-of-cycle
EOCLB	end-of-cycle licensing basis
EOC-RPT-OOS	end-of-cycle recirculation pump trip out-of-service
EOD	extended operating domain
EOFP	end of full power
EOOS	equipment out-of-service
FFTR	final feedwater temperature reduction
FHOOS	feedwater heaters out-of-service
FSAR	final safety analysis report
FW	feedwater
FWCF	feedwater controller failure
HCOM	hot channel oscillation magnitude
HFR	heat flux ratio
HPCI	high pressure coolant injection

Nomenclature
(Continued)

ICF	increased core flow
IHPS	inadvertent HPCI pump start
LFWH	loss of feedwater heating
LHGR	linear heat generation rate
$LHGRFAC_f$	flow-dependent linear heat generation rate multipliers
$LHGRFAC_p$	power-dependent linear heat generation rate multipliers
LOCA	loss-of-coolant accident
LPRM	local power range monitor
LRNB	generator load rejection with no bypass
MAPFAC	maximum average planar multipliers
MAPLHGR	maximum average planar linear heat generation rate
MCPR	minimum critical power ratio
$MCPR_f$	flow-dependent minimum critical power ratio
$MCPR_p$	power-dependent minimum critical power ratio
MELLLA	maximum extended load line limit analysis
MSIV	main steam isolation valve
MSRV	main steam relief valve
MSRVOOS	main steam relief valve out-of-service
NEOC	near end-of-cycle
NSS	nominal scram speed
NRC	Nuclear Regulatory Commission, U.S.
OLMCPR	operating limit minimum critical power ratio
OLTP	original licensed thermal power
OPRM	oscillation power range monitor
OSS	optimum scram speed
P_{bypass}	power below which direct scram on TSV/TCV closure is bypassed
PCT	peak cladding temperature
PLU	power load unbalance
PLUOOS	power load unbalance out-of-service
PRFO	pressure regulator failure open
RBM	(control) rod block monitor
RCPOOS	recirculation pump out-of-service
RHR	residual heat removal
RPT	recirculation pump trip

Nomenclature

(Continued)

SLC	standby liquid control
SLMCPR	safety limit minimum critical power ratio
SLO	single-loop operation
SS	steady state
TBVOOS	turbine bypass valves out-of-service
TCV	turbine control valve
TIP	traversing incore probe
TIPOOS	traversing incore probe out-of-service
TLO	two-loop operation
TSSS	technical specifications scram speed
TSV	turbine stop valve
TTNB	turbine trip with no bypass
TVA	Tennessee Valley Authority
ΔCPR	change in critical power ratio

1.0 Introduction

Reload licensing analyses results generated by AREVA Inc. (AREVA) are presented in support of cycle operation. The analyses reported in this document were performed using methodologies previously approved for generic application to boiling water reactors. The Nuclear Regulatory Commission, U.S. (NRC) technical limitations associated with the application of the approved methodologies has been satisfied by these analyses.

The Browns Ferry Unit 1 Cycle 12 (BFE1-12) core consists of a total of 764 fuel assemblies, including 280 fresh ATRIUM™ 10XM* assemblies and 484 irradiated ATRIUM-10 assemblies. Licensing analyses support the core design presented in Reference 1.

Reload licensing analyses were performed for potentially limiting events and analyses identified in Section 2. Results of analyses are used to establish the Technical Specifications/COLR limits and ensure design and licensing criteria are met. Design and safety analyses are based on both operational assumptions and plant parameters provided by the utility. The results of the reload licensing analysis support operation for the power/flow map presented in Figure 1.1 and also support operation with the equipment out-of-service (EOOS) scenarios presented in Table 1.1.

* ATRIUM is a trademark of AREVA Inc.

Table 1.1 EOD and EOOS
Operating Conditions

Extended Operating Domain (EOD) Conditions
Increased core flow (ICF)
Maximum extended load line limit analysis (MELLLA)
Combined final feedwater temperature reduction (FFTR) / coastdown
Equipment Out-of-Service (EOOS) Conditions*
Turbine bypass valves out-of-service (TBVOOS)
Feedwater heaters out-of-service (FHOOS)
Power load unbalance out-of-service (PLUOOS)
Combined TBVOOS and FHOOS
Combined TBVOOS and PLUOOS
Combined FHOOS and PLUOOS
Combined TBVOOS, FHOOS, and PLUOOS
Recirculation Pump out-of-service (RCPOOS)†

* Base case and each EOOS condition is supported in combination with 1 MSRVOOS, EOC-RPT-OOS, up to 2 traversing incore probe (TIP) machines out-of-service (TIPOOS) or the equivalent number of TIP channels (per operating requirements defined in Section 4.2), and/or up to 50% of the LPRMs out-of-service.

† RCPOOS is the EOOS implying single loop operation. RCPOOS thermal limit sets are provided for the EOOS conditions specified in Table 8.6. Operation in SLO is only supported up to a maximum core flow of 50% of rated, a maximum power level of 50% of rated, and an active recirculation drive flow of 17.73 Mlb/hr.

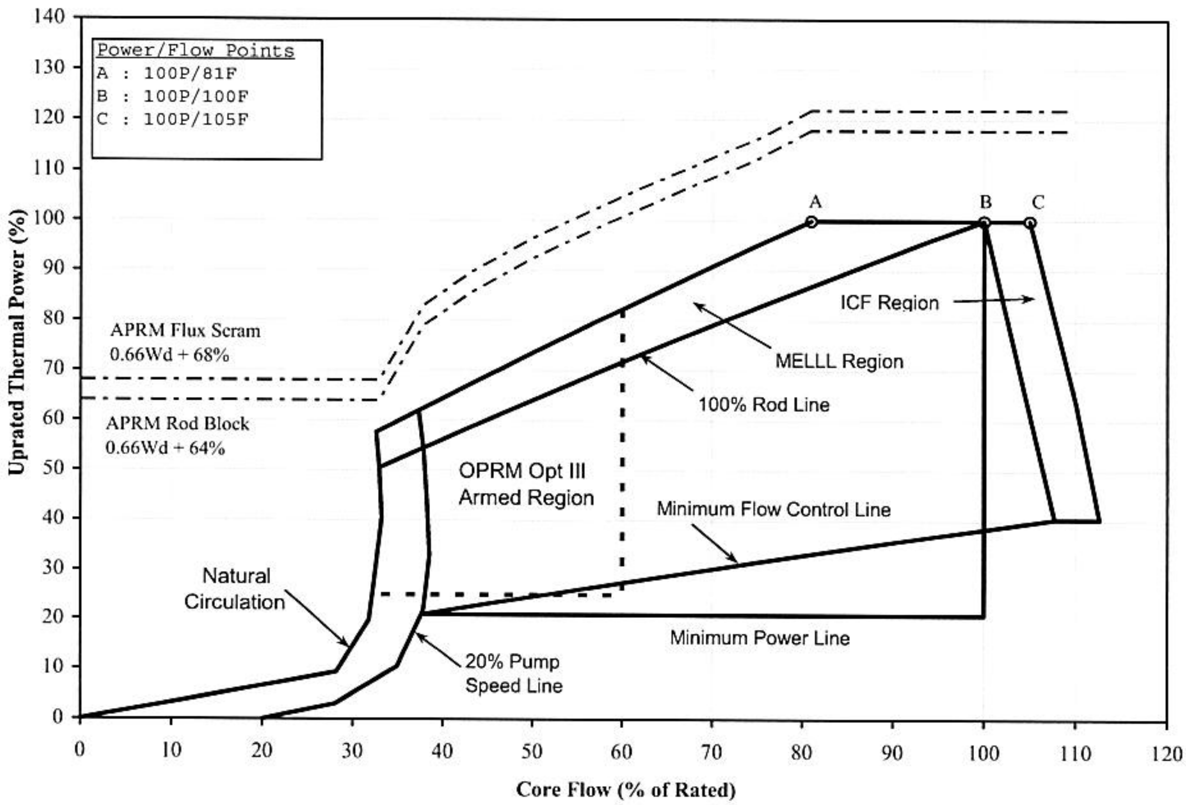

Figure 1.1 Browns Ferry Power/Flow Map – 105% OLTP

2.0 Disposition of Events

A review of FSAR events was previously performed to support introduction of ATRIUM 10XM fuel (Reference 2). The goal of Reference 2 was to identify potentially limiting events and analyses, which required evaluation either on a cycle-specific basis or generically. When changes to plant configurations are implemented, it warrants a review of Reference 2 conclusions.

The ATRIUM 10XM reload consists of 152 fuel assemblies that contain blended low-enriched uranium (BLEU) and 128 fuel assemblies that contain commercial grade uranium (CGU). BLEU fuel was previously addressed in Reference 3. Reference 3 remains applicable for BFE1-12. The calculation plan for BFE1-12 reload licensing analyses was based on these dispositions.

Parameter differences between the initial Browns Ferry ATRIUM 10XM licensing analyses and the BFE1-12 reload were reviewed to determine if the conclusions remain applicable. The review concluded that affected analyses were included in Reference 4.

3.0 Mechanical Design Analysis

NRC approved exposure limits for ATRIUM 10XM are presented in References 5 and 6. ATRIUM-10 fuel exposure limits are presented in Reference 8. The maximum exposure limits for the reload fuel are:

54.0 GWd/MTU average assembly exposure
62.0 GWd/MTU rod average exposure (full-length fuel rods)

Fuel cycle design analyses (Reference 1) verified all fuel assemblies remain within licensed burnup limits.

The maximum calculated rod oxide thickness is presented in Tables 3-2 and 3-3 of Reference 6 for ATRIUM 10XM fuel. The calculated oxide thickness complies with the limit provided in Section 3.2.7 of Reference 7.

LHGR limits are presented in Section 8.0.

4.0 Thermal-Hydraulic Design Analysis

4.1 *Thermal-Hydraulic Design and Compatibility*

Results of thermal-hydraulic characterization and compatibility analyses are presented in Reference 9. Analysis results demonstrate the thermal-hydraulic design and compatibility criteria are satisfied for the transition core consisting of ATRIUM 10XM and ATRIUM-10.

4.2 *Safety Limit MCPR Analysis*

The safety limit MCPR (SLMCPR) is defined as the minimum value of the critical power ratio ensuring less than 0.1% of the fuel rods are expected to experience boiling transition during normal operation, or an abnormal operational transient (AOT). The SLMCPR for all fuel was determined using the methodology described in Reference 10. The analysis was performed with a power distribution conservatively representing expected reactor operation throughout the cycle.

SLMCPR analysis used the ACE/ATRIUM 10XM critical power correlation (References 11 and 12) for the ATRIUM 10XM fuel while the SPCB critical power correlation (Reference 13) is used for the ATRIUM-10 fuel.

In the AREVA methodology, the effects of channel bow on the critical power performance are accounted for in the SLMCPR analysis. Reference 10 discusses the application of a realistic channel bow model. For BFE1-12, the channel bow model uncertainty has been augmented for those channels that experience fluence gradients outside the bounds of the measurement database.

Plant-related uncertainties used in the SLMCPR analysis are presented in Table 4.1. The radial power uncertainty used in the analysis includes the effects of up to 40% of the TIP channels out-of-service, up to 50% of the LPRMs out-of-service, and a 2500 EFPH LPRM calibration interval.

Analysis results support two-loop operation (TLO) SLMCPR of 1.06 and single-loop operation (SLO) SLMCPR of 1.08. Analysis results including the SLMCPR and the percentage of rods expected to experience boiling transition are summarized in Table 4.2.

4.3 *Core Hydrodynamic Stability*

Browns Ferry has implemented BWROG Long Term Stability Solution Option III (Oscillation Power Range Monitor-OPRM). Reload validation has been performed in accordance with Reference 14. The stability based Operating Limit MCPR (OLMCPR) is provided for two conditions as a function of OPRM amplitude setpoint in Table 4.3. The two conditions evaluated are for a postulated oscillation at 45% core flow steady state operation (SS) and following a two recirculation pump trip (2PT) from the limiting full power operation state point. Power- and Flow-dependent limits provide adequate protection against violation of the SLMCPR for postulated reactor instability as long as the operating limit is greater than or equal to the specified value for the selected OPRM setpoint. Setpoints supporting EOOS operating conditions are provided in Table 4.3.

DIVOM calculations are performed to obtain the relative change in CPR as a function of the calculated hot channel oscillation magnitude (HCOM). Analyses were performed in accordance with Reference 15. The methodology employs a coupled neutronic-thermal-hydraulic three-dimensional transient model for the purpose of determining the relationship between the relative change in ΔCPR and the HCOM on a plant specific basis. The method was developed consistent with the recommendations of the BWROG in Reference 16. Generation of plant-specific DIVOM data is consistent with Reference 17. The stability-based OLMCPRs were calculated using the most limiting calculated change in relative ΔCPR for a given oscillation magnitude.

In cases where the OPRM system is declared inoperable, Backup Stability Protection (BSP) is provided in accordance with Reference 18. BSP curves have been evaluated using an approved methodology (Reference 19) to determine endpoints meeting decay ratio criteria for the BSP Base Minimal Region I (scram region) and Base Minimal Region II (controlled entry region). Stability boundaries based on these endpoints identified in Table 4.4, are shown in Table 4.5 and Table 4.6, based on the generic shape generating function from Reference 18. Analyses have been performed to support operation for both nominal and reduced feedwater temperature conditions (both FFTR and FHOOS).

Acceptance criteria for the BSP endpoints are global decay ratios < 0.85 and regional and channel decay ratios < 0.80. Endpoints for the BSP regions provided in Table 4.4 have global decay ratios < 0.85, and regional and channel decay ratios < 0.80.

Table 4.1 Plant-Related Uncertainties for Safety Limit MCPR Analyses

Parameter	Uncertainty
Feedwater flow rate	1.8%
Feedwater temperature	0.8%
Core pressure	0.7%
Total core flow rate	
TLO	2.5%
SLO	6.0%

Table 4.2 Results Summary for Safety Limit MCPR Analyses

SLMCPR	Percentage of Rods in Boiling Transition
TLO – 1.06	0.039
SLO – 1.08	0.032

Table 4.3 OPRM Setpoints

OPRM Setpoint	OLMCPR (SS)	OLMCPR (2PT)
1.05	1.15	1.17
1.06	1.17	1.19
1.07	1.19	1.21
1.08	1.20	1.23
1.09	1.22	1.25
1.10	1.24	1.27
1.11	1.26	1.29
1.12	1.28	1.31
1.13	1.30	1.33
1.14	1.33	1.35
1.15	1.35	1.38
Acceptance Criteria	Off-Rated OLMCPR at 45% Flow	Rated Power OLMCPR as described in Section 8.0

Table 4.4 BSP Endpoints*

Feedwater Temperature Operation Mode	Region	End Point Designation	Power (% rated)	Flow (% rated)
Nominal	Scram	IA	63.72	40.00
Nominal	Scram	IB	43.88	29.00
Nominal	Controlled entry	IIA	73.46	50.00
Nominal	Controlled entry	IIB	30.72	29.00
FFTR/ FHOOS	Scram	IA	71.56	48.00
FFTR/ FHOOS	Scram	IB	40.00	29.00
FFTR/ FHOOS	Controlled entry	IIA	73.46	50.00
FFTR/ FHOOS	Controlled entry	IIB	30.72	29.00

* The shaded entries indicate that the nominal BSP regions (Figure 6.5 of Reference 20) were extended in order to meet decay ratio limits. The results presented are bounding results from Cycle 11.

Table 4.5 Nominal Feedwater Temperature Boundary Points

Scram Region		Exit Region	
Flow (% rated)	Power (% rated)	Flow (% rated)	Power (% rated)
40.00	63.72	50.00	73.46
39.45	61.99	48.95	68.89
38.90	60.36	47.90	64.74
38.35	58.84	46.85	60.97
37.80	57.40	45.80	57.55
37.25	56.05	44.75	54.44
36.70	54.79	43.70	51.61
36.15	53.60	42.65	49.03
35.60	52.48	41.60	46.68
35.05	51.44	40.55	44.55
34.50	50.47	39.50	42.60
33.95	49.56	38.45	40.83
33.40	48.71	37.40	39.21
32.85	47.92	36.35	37.75
32.30	47.19	35.30	36.41
31.75	46.51	34.25	35.20
31.20	45.89	33.20	34.11
30.65	45.31	32.15	33.12
30.10	44.79	31.10	32.23
29.55	44.31	30.05	31.43
29.00	43.88	29.00	30.72

Table 4.6 Reduced Feedwater Temperature Boundary Points*

Scram Region		Exit Region	
Flow (% rated)	Power (% rated)	Flow (% rated)	Power (% rated)
48.00	71.56	50.00	73.46
47.05	68.56	48.95	68.89
46.10	65.77	47.90	64.74
45.15	63.19	46.85	60.97
44.20	60.81	45.80	57.55
43.25	58.59	44.75	54.44
42.30	56.54	43.70	51.61
41.35	54.64	42.65	49.03
40.40	52.88	41.60	46.68
39.45	51.25	40.55	44.55
38.50	49.75	39.50	42.60
37.55	48.36	38.45	40.83
36.60	47.08	37.40	39.21
35.65	45.89	36.35	37.75
34.70	44.80	35.30	36.41
33.75	43.81	34.25	35.20
32.80	42.89	33.20	34.11
31.85	42.06	32.15	33.12
30.90	41.30	31.10	32.23
29.95	40.62	30.05	31.43
29.00	40.00	29.00	30.72

* The shaded entries indicate that the nominal BSP regions were extended in order to meet decay ratio limits.

5.0 Anticipated Operational Occurrences

This section describes the analyses performed to determine the power- and flow-dependent MCPR operating limits for base case operation.

COTRANSA2 (Reference 21), XCOBRA-T (Reference 22), XCOBRA (Reference 23), and CASMO-4/MICROBURN-B2 (Reference 24) are the major codes used in the thermal limits analyses as described in the AREVA THERMEX methodology report (Reference 23) and neutronics methodology report (Reference 24). COTRANSA2 is a system transient simulation code, which includes an axial one-dimensional neutronics model that captures the effects of axial power shifts associated with the system transients. XCOBRA-T is a transient thermal-hydraulics code used in the analysis of thermal margins for the limiting fuel assembly. XCOBRA is used in steady-state analyses. The ACE/ATRIUM 10XM critical power correlation (References 11 and 12) is used to evaluate the thermal margin for the ATRIUM 10XM fuel. The SPCB critical power correlation (Reference 13) is used to evaluate the thermal margin of the ATRIUM-10 fuel. Fuel pellet-to-cladding gap conductance values are based on RODEX2 (Reference 25) calculations for the BFE1-12 core.

5.1 *System Transients*

The reactor plant parameters for the system transient analyses were provided by the utility. Analyses have been performed to determine power-dependent MCPR limits protecting operation throughout the power/flow domain depicted in Figure 1.1.

At Browns Ferry, direct scram on turbine stop valve (TSV) position and turbine control valve (TCV) fast closure are bypassed at power levels less than 30% of rated (P_{bypass}). Below P_{bypass} scram occurs when either the high pressure, or high neutron flux scram setpoint is reached. MCPR limits are monitored at power levels greater than or equal to 25% of rated, which is the lowest power analyzed for this report, consistent with Reference 26.

The limiting exposure for rated power pressurization transients is typically at end of full power (EOFP) when the control rods are fully withdrawn. To provide additional margin to the operating limits earlier in the cycle, analyses were also performed to establish operating limits at a near end-of-cycle (NEOC) core average exposure of 29,949.1 MWd/MTU. Analyses were performed at cycle exposures prior to NEOC to ensure that the operating limits provide the necessary protection. The end-of-cycle licensing basis (EOCLB) analysis was performed at EOFP + 15 EFPD (core average exposure of 33,699.9 MWd/MTU). Analyses were also performed to support extended cycle operation with FFTR and power coastdown. The licensing basis exposures used to develop the neutronics inputs to the transient analyses are presented in Table 5.1.

All pressurization transients assumed one of the lowest setpoint main steam relief valves (MSRV) was inoperable. The basis supports operation with 1 MSRV out-of-service.

Reductions in feedwater temperature of less than 10°F from the nominal feedwater temperature and variation of ±10 psi in dome pressure are considered base case operation, not an EOOS condition. Analyses were performed to determine the limiting conditions in the allowable ranges.

FFTR is used to extend rated power operation by decreasing the feedwater temperature. The amount of feedwater temperature reduction is a function of power with the maximum decrease of 65°F (55°F + 10°F bias) at rated power. Analyses were performed to support combined FFTR/Coastdown operation to a core average exposure of 35,231.8 MWd/MTU. The analyses were performed with the limiting feedwater and dome pressure conditions in the allowable ranges.

System pressurization transient results are sensitive to scram speed assumptions. To take advantage of average scram speeds faster than those associated with the Technical Specifications requirements, scram speed-dependent $MCPR_p$ limits are provided. The optimum scram speed (OSS) insertion times, nominal scram speed (NSS) insertion times, and the Technical Specifications scram speed (TSSS) insertion times used in the analyses are presented in Table 5.2. The OSS and NSS $MCPR_p$ limits can only be applied if the scram speed test results meet the required insertion times. System transient analyses were performed to establish $MCPR_p$ limits for OSS, NSS, and TSSS insertion times. Technical Specifications (Reference 26) allow for operation with up to 13 “slow” and 1 stuck control rod. One additional control rod is assumed to fail to scram. Conservative adjustments to the OSS, NSS, and TSSS insertion times were made to the analysis inputs to appropriately account for these effects on scram reactivity. For cases below 30% power, the results are relatively insensitive to scram speed, and only TSSS analyses are performed. At 30% power (P_{bypass}), analyses were performed, both with and without bypass of the direct scram function, resulting in an operating limits step change.

5.1.1 Load Rejection No Bypass (LRNB)

Load rejection causes a fast closure of the turbine control valves. The resulting compression wave travels through the steam lines into the vessel and creates a rapid pressurization. The increase in pressure causes a decrease in core voids, which in turn causes a rapid increase in power. Fast closure of the turbine control valves also causes a reactor scram and recirculation pump trip (RPT). Turbine bypass system operation, which also mitigates the consequences of the event, is not credited. The excursion of the core power due to the void collapse is terminated primarily by the reactor scram and revoiding of the core.

LRNB analyses assume the power load unbalance (PLU) is inoperable for power levels less than 50% of rated. The LRNB sequence of events is different than the standard event when the PLU is inoperable. Instead of a fast closure, the TCVs close in servo mode and there is no direct scram on TCV closure. The power and pressure excursion continues until the high pressure scram occurs.

LRNB analyses were performed for a range of power/flow conditions to support generation of the thermal limits. Base case limiting LRNB transient analysis results used to generate the NEOC and EOCLB operating limits are shown in Table 5.3. Responses of various reactor and plant parameters during the LRNB event initiated at 100% of rated power and 105% of rated core flow with TSSS insertion times are shown in Figures 5.1 – 5.3.

5.1.2 Turbine Trip No Bypass (TTNB)

A turbine trip event can be initiated as a result of several different signals. The initiating signal causes the TSV to close in order to prevent damage to the turbine. The TSV closure creates a compression wave traveling through the steam lines into the vessel causing a rapid pressurization. The increase in pressure results in a decrease in core voids, which in turn causes a rapid increase in power. Closure of the TSV also causes a reactor scram and an RPT which helps mitigate the pressurization effects. Turbine bypass system operation, which also mitigates the consequences of the event, is not credited. The excursion of the core power due to the void collapse is terminated primarily by the reactor scram and revoiding of the core.

In addition to closing the TSV, a signal is also sent to close the TCV in fast mode. The consequences of a fast closure of the TCV are very similar to those resulting from a TSV closure. The main difference is the time required to close the valves. While the TCV full stroke closure time is greater than that of the TSV (0.150 sec compared to 0.100 sec), the initial position of the TCV is dependent on the initial steam flow. At rated power and lower, the initial position of the TCV is such that the closure time is less than that of the TSV. However, the TCV closure characteristics are nonlinear such that the resulting core pressurization and ΔCPR may not always bound those of the slower TSV closure.

Analyses were performed demonstrating the TTNB event is equivalent to or bound by the LRNB event; therefore, the thermal limits established for the LRNB will also protect against the TTNB event.

5.1.3 Feedwater Controller Failure (FWCF)

The increase in feedwater flow due to a failure of the feedwater control system to maximum demand results in an increase in the water level and a decrease in the coolant temperature at the core inlet. The increase in core inlet subcooling causes an increase in core power. As the

feedwater flow continues at maximum demand, the water level continues to rise and eventually reaches the high water level trip setpoint. The initial water level is conservatively assumed to be at the low level normal operating range to delay the high-level trip and maximize the core inlet subcooling resulting from the FWCF. The high water level trip causes the TSVs to close in order to prevent damage to the turbine from excessive liquid inventory in the steam line. Valve closure creates a compression wave traveling back to the core, causing void collapse and subsequent rapid power excursion. The closure of the TSVs also initiates a reactor scram and an RPT. In addition to the TSV closure, the TCVs also close in the fast closure mode. Because of the partially closed initial position of the control valves, they will typically close faster than the stop valves and control the pressurization portion of the event. However, TCV closure characteristics are nonlinear so that the resulting core pressurization and ΔCPR results may not always bound those of the slower TSV closure at rated power (steam flow increases above rated before fast TCV closure). The limiting of TCV or TSV closure, for the initial operating conditions, was used in the FWCF analyses based on sensitivity analyses. The turbine bypass valves are assumed operable and provide some pressure relief. The core power excursion is mitigated in part by pressure relief, but the primary mechanisms for termination of the event are reactor scram and revoiding of the core.

FWCF analyses were performed for a range of power/flow conditions to support generation of the thermal limits. Analyses performed above P_{bypass} assumed a maximum feedwater runout of 22.79 Mlbm/hr. For below P_{bypass}, a maximum feedwater runout of 15.19 Mlbm/hr was assumed. A discussion of this input is provided in Comment 25 of Reference 20.

Table 5.4 presents the base case limiting FWCF transient analysis results used to generate the NEOC and EOCLB operating limits. Figures 5.4 – 5.6 show the responses of various reactor and plant parameters during the FWCF event initiated at 100% of rated power and 105% of rated core flow with TSSS insertion times.

5.1.4 Loss of Feedwater Heating

The loss of feedwater heating (LFWH) event analysis supports an assumed 100°F decrease in the feedwater temperature. The result is an increase in core inlet subcooling, which reduces voids, thereby increasing core power and shifting axial power distribution toward the bottom of the core. As a result of the axial power shift and increased core power, voids begin to build up

in the bottom region of the core, acting as negative feedback to the increased subcooling effect. The negative feedback moderates the core power increase. Although there is a substantial increase in core thermal power during the event, the increase in steam flow is much less because a large part of the added power is used to overcome the increase in inlet subcooling. The increase in steam flow is accommodated by the pressure control system via the TCVs or the turbine bypass valves, so no pressurization occurs. A cycle-specific analysis was performed in accordance with the Reference 27 methodology to determine the change in MCPR for the event. The LFWH results are presented in Table 5.5.

5.1.5 Control Rod Withdrawal Error

The control rod withdrawal error (CRWE) transient is an inadvertent reactor operator initiated withdrawal of a control rod. This withdrawal increases local power and core thermal power, lowering the core MCPR. The CRWE transient is typically terminated by control rod blocks initiated by the rod block monitor (RBM). The CRWE event was analyzed assuming no xenon and allowing credible instrumentation out-of-service in the RBM system. The analysis further assumes that the plant could be operating in either an A or B sequence control rod pattern. The rated power CRWE results are shown in Table 5.6 for the analytical unfiltered RBM high power setpoint values of 107% to 117%. Analysis results indicate standard filtered RBM setpoint reductions are supported. Analyses demonstrate the 1% strain and centerline melt criteria are met for ATRIUM 10XM and ATRIUM-10. LHGR limits and associated multipliers are presented in Section 8.2. Recommended operability requirements supporting unblocked CRWE operation are shown in Table 5.7, based on the SLMCPR values presented in Section 4.2. The $MCPR_P$ limits allow unblocked operation in Cycle 12.

5.2 *Slow Flow Runup Analysis*

Flow-dependent MCPR limits ($MCPR_f$) and LHGR multipliers ($LHGRFAC_f$) are established to support operation at off-rated core flow conditions. Limits are based on the CPR and heat flux changes experienced by the fuel during slow flow excursions. The slow flow excursion event assumes recirculation flow control system failure such that core flow increases slowly to the maximum flow physically attainable by the equipment (107% of rated core flow). An uncontrolled increase in flow creates the potential for a significant increase in core power and

heat flux. A conservatively steep flow runup path was used in the analysis. Evaluations were performed to support operation in all the EOOS scenarios.

A steady-state hydraulic model, using bounding statepoint assumptions, is used to calculate the change in critical power ratio during a two-loop flow runup to the maximum flow rate. The $MCPR_f$ limit is set so an increase in core power, resulting from the maximum increase in core flow, assures the TLO safety limit MCPR is not violated. Calculations were performed over a range of initial flow rates to determine the corresponding MCPR values causing the limiting assembly to be at the safety limit MCPR for the high flow condition at the end of the flow excursion.

Analysis results are presented in Table 5.8. $MCPR_f$ limits providing the required protection are presented in Table 8.7. $MCPR_f$ limits are applicable for all exposures.

Flow runup analyses were performed to determine $LHGRFAC_f$ multipliers. The analysis assumes recirculation flow increases slowly along the limiting rod line to the maximum flow physically attainable by the equipment. A series of flow excursion analyses were performed at several exposures throughout the cycle, starting from different initial power/flow conditions. Xenon is assumed to remain constant during the event. $LHGRFAC_f$ multipliers are established to provide protection against fuel centerline melt and overstraining of the cladding during a flow runup. $LHGRFAC_f$ multipliers are presented in Table 8.10.

The maximum flow during a flow excursion in SLO is much less than the maximum flow during TLO. Therefore, the flow-dependent MCPR limits and LHGR multipliers for TLO are applicable for SLO.

5.3 *Equipment Out-of-Service Scenarios*

The EOOS scenarios supported are shown in Table 1.1. As noted in Table 1.1, base case and each EOOS condition is supported in combination with 1 MSRVOOS, EOC-RPT-OOS, up to 2 TIP machines out-of-service or the equivalent number of TIP channels (per operating requirements defined in Section 4.2), and/or up to 50% of the LPRMs out-of-service.

When EOC-RPT is inoperable, no credit is assumed for RPT on TSV position or TCV fast closure. The function of the EOC-RPT feature is to reduce the severity of the core power excursion caused by the pressurization transient. The RPT accomplishes this by helping revoid the core, thereby reducing the magnitude of the reactivity insertion resulting from the pressurization transient. Failure of the RPT feature can result in higher operating limits. Analyses were performed for LRNB and FWCF events assuming EOC-RPT-OOS.

The analyses presented in this section also include these EOOS conditions protected by the base case limits. No further discussion for these EOOS conditions is presented in this section. Base thermal limits presented in Section 8.0 are applicable with or without function of the EOC-RPT.

5.3.1 TBVOOS

The effect of operation with TBVOOS is a reduction in the system pressure relief capacity, which makes the pressurization events more severe. While the base case LRNB and TTNB events are analyzed assuming the turbine bypass valves out-of-service, operation with TBVOOS has an adverse effect on the FWCF event. Analyses of the FWCF event with TBVOOS were performed to establish the TBVOOS operating limits.

5.3.2 FHOOS

The FHOOS scenario assumes a feedwater temperature reduction of 65°F (55°F + 10°F bias) at rated power and steam flow. The effect of reduced feedwater temperature is an increase in core inlet subcooling, changing axial power shape and core void fraction. Additionally, steam flow for a given power level decreases because more power is required to increase coolant enthalpy to saturated conditions. Generally, LRNB and TTNB events are less severe with FHOOS conditions due to the decrease in steam flow relative to nominal conditions. FWCF events with FHOOS conditions are generally worse due to a larger change in inlet subcooling and core power prior to the pressurization phase of the event.

Separate FHOOS limits are not needed for operation beyond the EOCLB exposure since a feedwater (FW) temperature reduction is included to attain the additional cycle extension to the FFTR/coastdown exposure, i.e., FFTR is equivalent to FHOOS since both are based on the same feedwater temperature reduction.

5.3.3 PLUOOS

The PLU device in normal operation is assumed to not function below 50% power. PLUOOS is assumed to mean the PLU device does not function for any power level, and does not initiate fast TCV closure. The following PLUOOS scenario was assumed for the load reject event.

- Initially, the TCVs remain in pressure/speed control mode. There is no direct scram or EOC-RPT on valve motion.
- Loss of load results in increasing turbine speed. Depending on initial power, a turbine overspeed condition may be reached to initiate a turbine trip resulting in scram and EOC-RPT.
- Without a turbine trip signal, scram occurs on either high flux or high dome pressure to terminate the event.

Analyses were performed for LRNB events assuming PLUOOS.

5.3.4 Combined TBVOOS and FHOOS

FWCF analyses with both TBVOOS and FHOOS were performed. Operating limits for this combined EOOS scenario were established using these FWCF results and results previously discussed. Separate TBVOOS and FHOOS combined limits are not needed for operation beyond the EOCLB exposure since a FW temperature reduction is included to attain the additional cycle extension to the FFTR/coastdown exposure.

5.3.5 Combined TBVOOS and PLUOOS

Limits were established to support operation with both TBVOOS and PLUOOS. No additional analyses are required to construct $MCPR_p$ operating limits for TBVOOS and PLUOOS since TBVOOS and PLUOOS are independent EOOS conditions (TBVOOS only impacts FWCF events; PLUOOS only impacts LRNB events).

5.3.6 Combined FHOOS and PLUOOS

LRNB analyses with both FHOOS and PLUOOS were performed. Operating limits for this combined EOOS scenario were established using these LRNB results and results previously discussed. Separate FHOOS and PLUOOS combined limits are not needed for operation beyond the EOCLB exposure since a FW temperature reduction is included to attain the additional cycle extension to the FFTR/coastdown exposure.

5.3.7 Combined TBVOOS, FHOOS, and PLUOOS

Limits were established to support operation with TBVOOS, FHOOS, and PLUOOS. No additional analyses are required to construct $MCPR_p$ operating limits for TBVOOS, FHOOS, and PLUOOS since TBVOOS and PLUOOS are independent EOOS conditions (TBVOOS only impacts FWCF events; PLUOOS only impacts LRNB events). Separate TBVOOS, FHOOS, and PLUOOS combined limits are not needed for operation beyond the EOCLB exposure since a FW temperature reduction is included to attain the additional cycle extension to the FFTR/coastdown exposure.

5.3.8 Reduced Feedwater Temperature at Startup

During reactor startup, it is beneficial to reduce feedwater temperature to avoid excessive wear on reactor equipment. The desired feedwater temperature is less than the temperature assumed in the FHOOS licensing analyses performed each cycle. Therefore, previously defined EOOS scenarios are not adequate to cover operation during startup with the desired reduction in feedwater temperature.

Analyses were performed to support all cycle exposures with or without EOC-RPT-OOS. Analyses were also performed to support all cycle exposures with TBVOOS in combination with or without EOC-RPT-OOS. The analyses consider both NSS (above P_{bypass} cases) and TSSS. In addition, these analyses inherently cover all remaining non-PLUOOS equipment out-of-service scenarios defined in Table 1.1. Two separate startup feedwater temperatures are evaluated, the temperature provided in Item 6.6.1 of Reference 20 and a 5°F reduction from these temperatures. Limits for startup feedwater temperatures are presented in Table 8.4, Table 8.5, and Table 8.9.

The reduced feedwater temperatures are not applicable above 50% of rated power. The startup feedwater temperatures cannot be less than the values defined in Item 6.6.1 of Reference 20. If this requirement is met, reactor startup is restricted to the 100% rod line or less. The 95% rod line or less is required if the feedwater temperatures are no more than 5°F lower than Item 6.6.1 of Reference 20.

5.3.9 Recirculation Pump Out-of-Service

Recirculation pump out-of-service (RCPOOS) is the EOOS implying single loop operation. The pump seizure event assumes the reactor is operating with one recirculation pump inactive and an instantaneous seizure of the pump motor shaft of the active recirculation pump occurs. Flow through the active loop is rapidly reduced due to the large hydraulic resistance introduced by the stopped rotor causing core thermal power to decrease and reactor water level to swell. The sudden decrease in core coolant flow while the reactor is at power results in a degradation of core heat transfer which could result in fuel damage. The high water level setpoint is not reached, therefore no reactor scram occurs.

Analyses assumptions have been constructed to seek a balance between operating flexibility and margin to thermal limits. Maximum core power and flow are restricted to 50% of rated; active recirculation drive flow is assumed ≤ 17.73 Mlb/hr. The results for the SLO pump seizure event are provided in Table 5.9.

For RCPOOS, the TLO transient ΔCPRs and LHGRFAC multipliers remain applicable. Therefore, when developing the thermal limits, the only impacts on the LHGR and MAPLHGR limits is the application of a MAPLHGR multiplier discussed in Section 8.3. The same situation is true for the EOOS scenarios. The TLO EOOS LHGRFAC multipliers remain applicable.

5.4 *Licensing Power Shape*

The licensing axial power profile used by AREVA for the plant transient analyses bounds the projected end of full power axial power profile. The conservative licensing axial power profile generated at the EOCLB core average exposure of 33,699.9 MWd/MTU is given in Table 5.10. Operation is considered to be in compliance when:

- The integrated normalized power generated in the bottom 7 nodes from the projected EOFP solution at the state conditions provided in Table 5.10 is greater than the integrated normalized power generated in the bottom 7 nodes in the licensing basis axial power profile, *and* the individual normalized power from the projected EOFP solution is greater than the corresponding normalized power from the licensing basis axial power profile for at least 6 of the 7 bottom nodes.
- The projected EOFP condition occurs at a core average exposure less than or equal to EOCLB.

If the criteria cannot be fully met, the licensing basis may nevertheless remain valid but further assessment will be required.

The licensing basis power profile in Table 5.10 was calculated using the MICROBURN-B2 code. Compliance analyses must also be performed using MICROBURN-B2 or POWERPLEX®-XD*. Note that the power profile comparison should be done without incorporating instrument updates to the axial profile because the updated power is not used in the core monitoring system to accumulate assembly burnups.

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* POWERPLEX is a trademark of AREVA Inc. registered in the United States and various other countries.

Table 5.1 Exposure Basis for Transient Analysis

Core Average Exposure (MWd/MTU)	Comments
16,949.5	Beginning of cycle
29,949.1	Break point for exposure-dependent $MCPR_p$ limits (NEOC)
33,699.9	Design basis rod patterns to EOFP + 15 EFPD (EOCLB)
35,231.8	Maximum licensing core exposure - including FFTR /Coastdown
33,189.1 (17,144.9)*	Cycle 11 EOC (nominal value)
32,760.0 (16,715.7)*	Cycle 11 EOC (short window)
33,454.1 (17,409.8)*	Cycle 11 EOC (long window)

* Corresponding Cycle 11 cycle exposure.

Table 5.2 Scram Speed Insertion Times

Control Rod Position (notch)	TSSS Analytical Time (sec)	NSS Analytical Time (sec)	OSS Analytical Time (sec)
48 (*full-out*)	0.00	0.00	0.00
48	0.20	0.20	0.20
46	0.46	0.421	0.392
36	1.09	0.991	0.887
26	1.86	1.62	1.487
6	3.50	3.04	3.04
0 (*full-in*)	4.0	3.5	3.5

Table 5.3 Base Case LRNB Transient Results

Power (% rated)	NEOC			EOCLB		
	A10XM ΔCPR	AT10 ΔCPR	AT10 HFR	A10XM ΔCPR	AT10 ΔCPR	AT10 HFR
TSSS Insertion Times						
100	0.32	0.36	1.33	0.33	0.38	1.38
90	0.32	0.37	1.33	0.34	0.38	1.38
75	0.32	0.36	1.32	0.33	0.37	1.37
50	0.74	0.87	1.80	0.76	0.87	1.80
40	0.82	0.95	1.89	0.82	0.95	1.89
30 at > 50%F below P_{bypass}	0.94	1.03	1.96	0.94	1.03	1.96
30 at ≤ 50%F below P_{bypass}	0.81	0.95	1.72	0.81	0.95	1.72
25 at > 50%F below P_{bypass}	1.05	1.09	2.01	1.05	1.09	2.01
25 at ≤ 50%F below P_{bypass}	0.91	1.05	1.80	0.91	1.05	1.80
NSS Insertion Times						
100	0.30	0.35	1.31	0.32	0.36	1.38
90	0.31	0.35	1.32	0.33	0.37	1.37
75	0.31	0.35	1.31	0.32	0.36	1.36
50	0.73	0.86	1.80	0.74	0.86	1.80
40	0.81	0.94	1.88	0.81	0.94	1.88
30	0.93	1.02	1.95	0.93	1.02	1.95
OSS Insertion Times						
100	0.28	0.32	1.30	0.31	0.35	1.37
90	0.29	0.33	1.31	0.31	0.35	1.37
75	0.29	0.33	1.31	0.31	0.34	1.36
50	0.73	0.86	1.79	0.73	0.86	1.79
40	0.81	0.94	1.88	0.81	0.94	1.88
30	0.93	1.02	1.95	0.93	1.02	1.95

Table 5.4 Base Case FWCF Transient Results

Power (% rated)	*NEOC*			*EOCLB*		
	A10XM ΔCPR	AT10 ΔCPR	AT10 HFR	A10XM ΔCPR	AT10 ΔCPR	AT10 HFR
			TSSS Insertion Times			
100	0.38	0.41	1.42	0.38	0.42	1.43
90	0.41	0.46	1.47	0.41	0.46	1.48
75	0.48	0.52	1.55	0.48	0.52	1.55
65	0.54	0.61	1.61	0.54	0.61	1.61
60	0.57	0.66	1.65	0.57	0.66	1.65
50	0.71	0.82	1.74	0.71	0.82	1.74
40	0.92	1.05	1.89	0.92	1.05	1.89
30	1.19	1.38	2.08	1.19	1.38	2.08
30 at > 50%F below P_{bypass}	1.40	1.32	2.18	1.40	1.32	2.18
30 at ≤ 50%F below P_{bypass}	1.15	1.30	2.18	1.15	1.30	2.18
25 at > 50%F below P_{bypass}	1.42	1.54	2.33	1.42	1.54	2.33
25 at ≤ 50%F below P_{bypass}	1.33	1.48	2.19	1.33	1.48	2.19
			NSS Insertion Times			
100	0.36	0.40	1.40	0.37	0.40	1.42
90	0.40	0.44	1.46	0.41	0.44	1.47
75	0.47	0.51	1.52	0.47	0.51	1.54
65	0.53	0.57	1.58	0.53	0.57	1.60
60	0.57	0.63	1.62	0.57	0.63	1.62
50	0.68	0.78	1.72	0.68	0.78	1.72
40	0.89	1.01	1.87	0.89	1.01	1.87
30	1.17	1.34	2.07	1.17	1.34	2.07

Table 5.4 Base Case FWCF Transient Results *(Continued)*

Power (% rated)	*NEOC*			*EOCLB*		
	A10XM ΔCPR	AT10 ΔCPR	AT10 HFR	A10XM ΔCPR	AT10 ΔCPR	AT10 HFR
OSS Insertion Times						
100	0.35	0.37	1.38	0.36	0.39	1.40
90	0.39	0.43	1.44	0.40	0.43	1.46
75	0.46	0.50	1.51	0.46	0.50	1.53
65	0.52	0.56	1.57	0.52	0.56	1.59
60	0.56	0.60	1.60	0.56	0.60	1.61
50	0.66	0.75	1.70	0.66	0.75	1.70
40	0.87	0.98	1.85	0.87	0.98	1.85
30	1.15	1.30	2.05	1.15	1.30	2.05

Table 5.5 Loss of Feedwater Heating Transient Analysis Results

Power (% rated)	ΔCPR*
100	0.14
90	0.15
80	0.16
70	0.17
60	0.18
50	0.20
40	0.22
30	0.27
25	0.31

Table 5.6 Control Rod Withdrawal Error ΔCPR Results

Analytical RBM Setpoint (without filter) (%)	ΔCPR*	CRWE MCPR†
107	0.29	1.35
111	0.30	1.36
114	0.30	1.36
117	0.35	1.41

* Results are for the most limiting of the ATRIUM 10XM or ATRIUM-10 fuel in the core.

† For rated power and a 1.06 SLMCPR.

Table 5.7 RBM Operability Requirements

Thermal Power (% rated)	Applicable MCPR
≥ 27% and < 90%	1.75 TLO 1.79 SLO
≥ 90%	1.43 TLO

Table 5.8 Flow-Dependent MCPR Results

Core Flow (% rated)	ATRIUM 10XM	ATRIUM-10
30	1.46	1.50
40	1.39	1.41
50	1.37	1.37
60	1.35	1.33
70	1.29	1.28
80	1.22	1.24
90	1.18	1.20
100	1.14	1.16
107	1.06	1.09

Table 5.9 RCPOOS Pump Seizure Results

State point Power / Flow (% rated)	ATRIUM 10XM ΔCPR	ATRIUM-10 ΔCPR
50 / 50	0.94	0.87

Table 5.10 Licensing Basis Core Average Axial Power Profile

State Conditions for Power Shape Evaluation	
Power, MWt	3458.0
Core pressure, psia	1050.1
Inlet subcooling, Btu/lbm	24.2
Flow, Mlb/hr	107.6
Control state	ARO
Core average exposure (EOCLB), MWd/MTU	33,699.9

Licensing Axial Power Profile
(Normalized)

Node	Power
Top 25	0.299
24	0.844
23	1.075
22	1.224
21	1.300
20	1.339
19	1.355
18	1.360
17	1.340
16	1.401
15	1.392
14	1.341
13	1.366
12	1.327
11	1.264
10	1.189
9	1.106
8	0.989
7	0.850
6	0.723
5	0.596
4	0.490
3	0.413
2	0.322
Bottom 1	0.095

Sum of Bottom 7 Nodes = 3.489

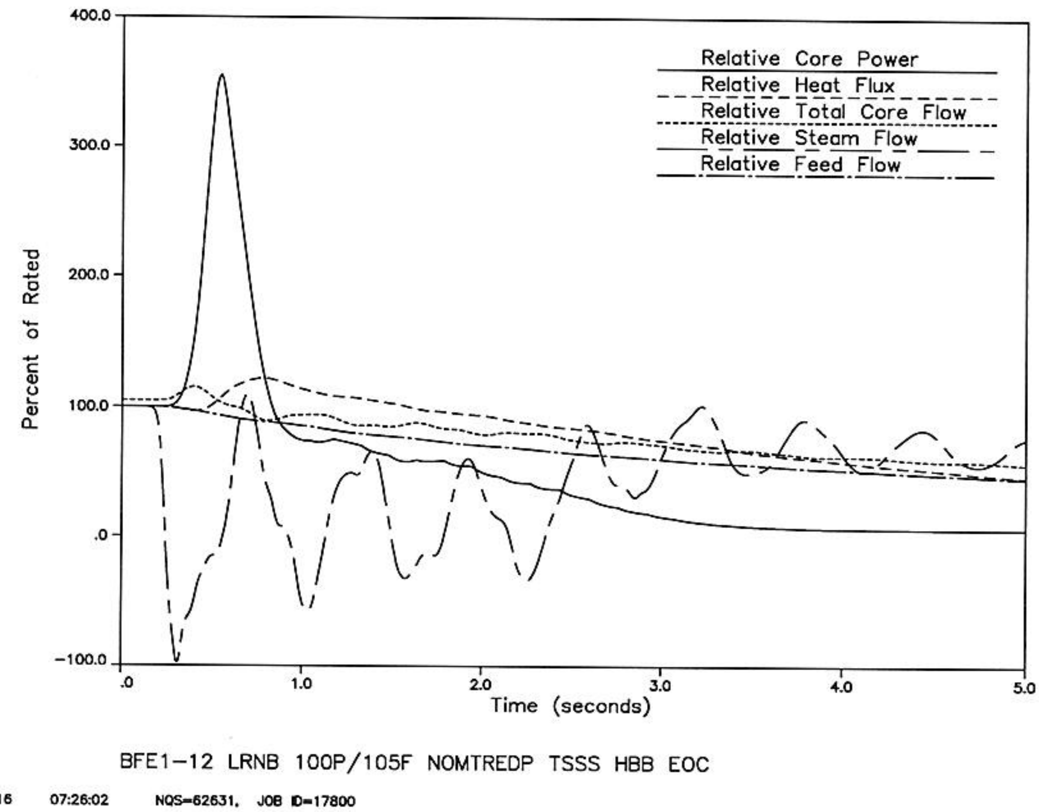

Figure 5.1 EOCLB LRNB at 100P/105F – TSSS Key Parameters

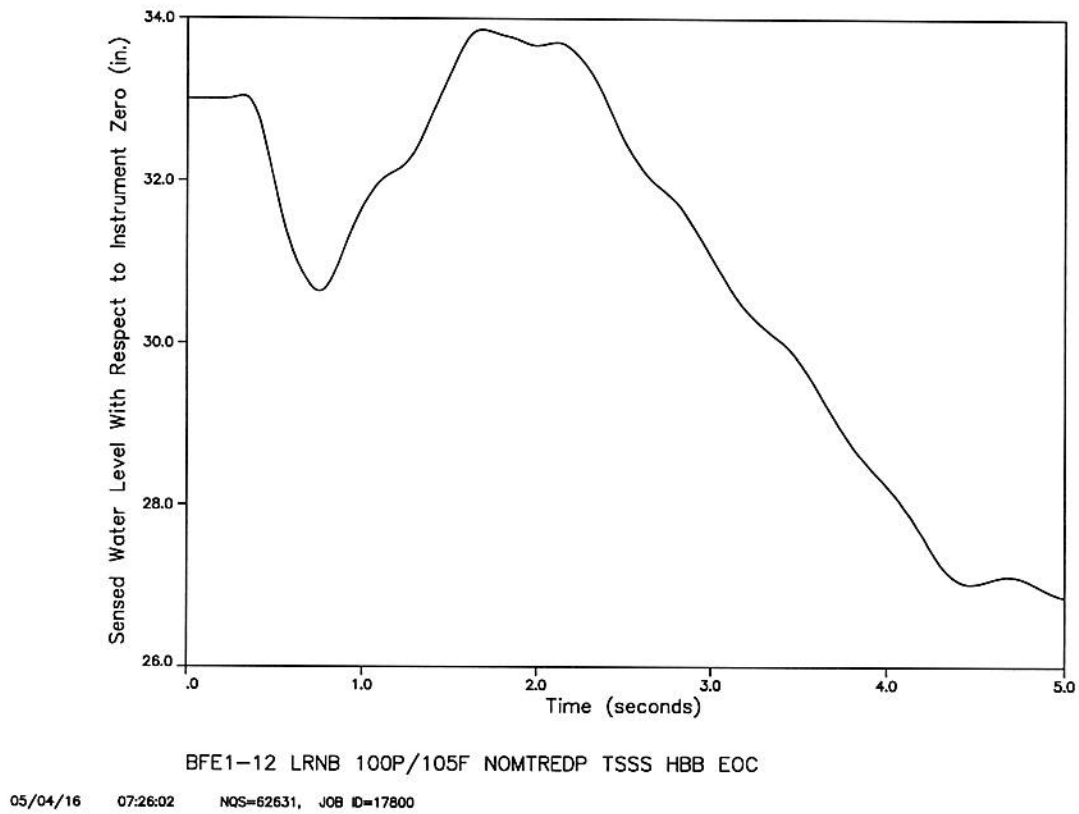

Figure 5.2 EOCLB LRNB at 100P/105F – TSSS Sensed Water Level

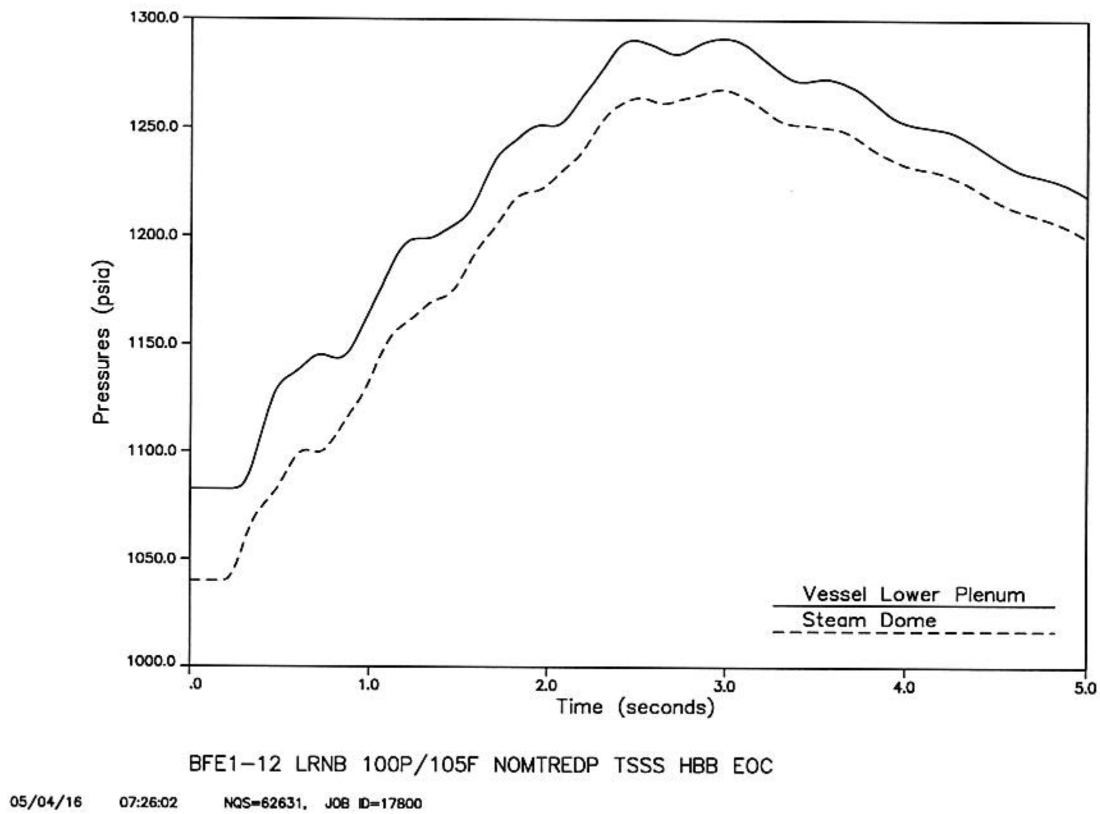

Figure 5.3 EOCLB LRNB at 100P/105F – TSSS
Vessel Pressures

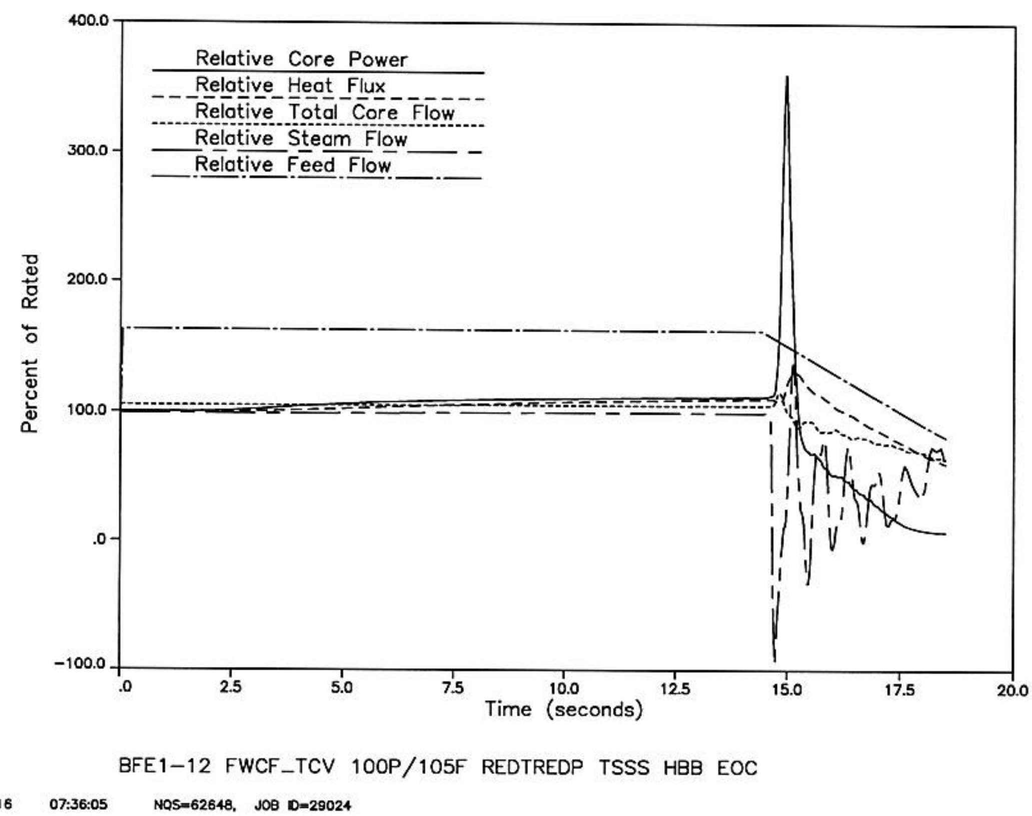

Figure 5.4 EOCLB FWCF at 100P/105F – TSSS Key Parameters

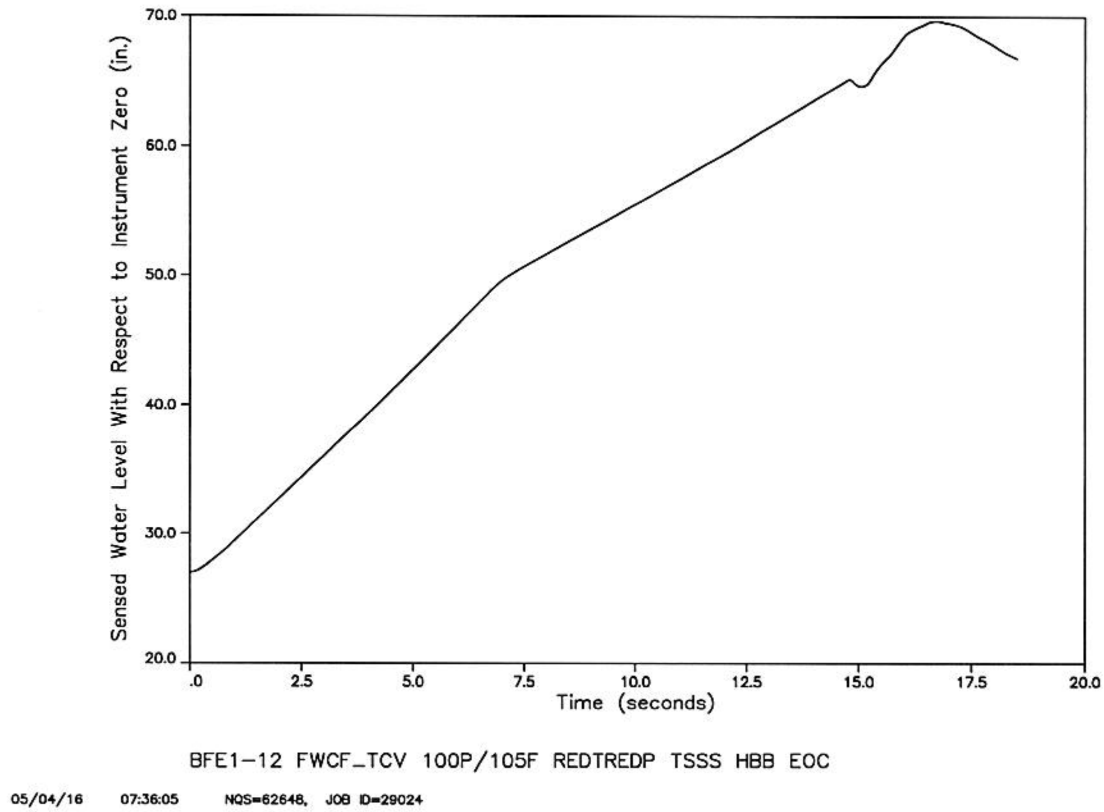

Figure 5.5 EOCLB FWCF at 100P/105F – TSSS Sensed Water Level

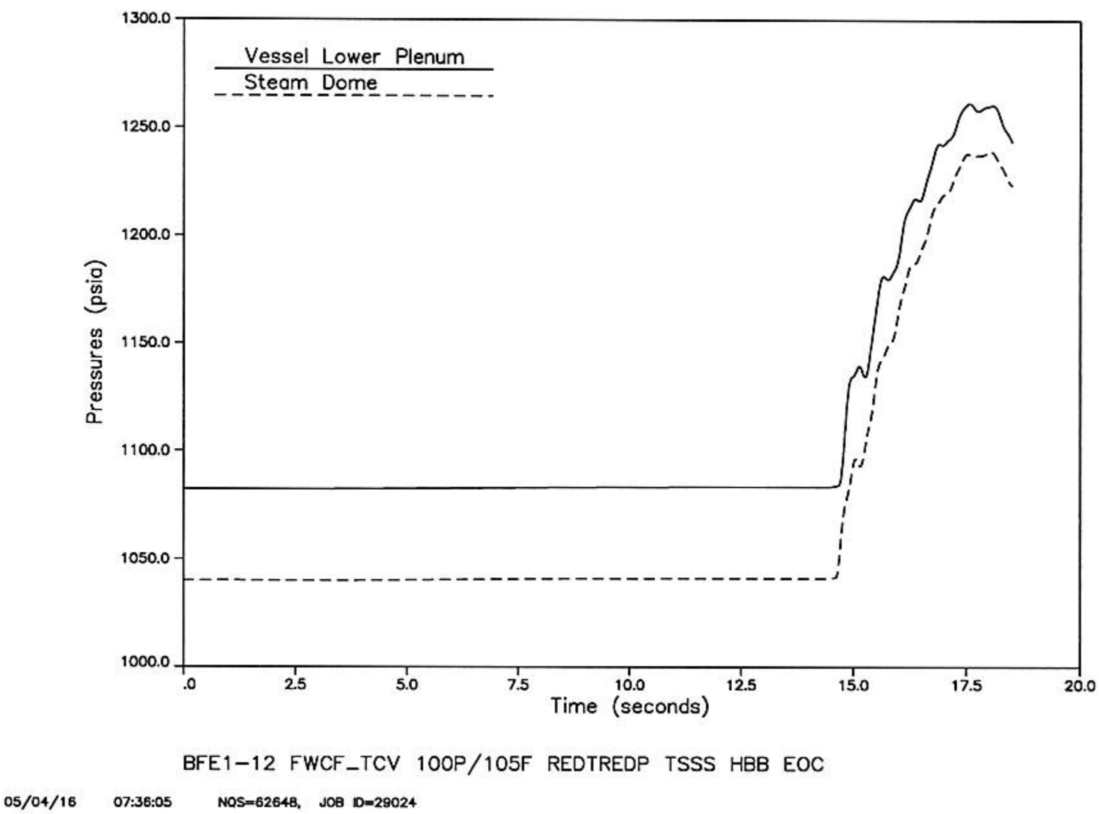

Figure 5.6 EOCLB FWCF at 100P/105F – TSSS Vessel Pressures

6.0 Postulated Accidents

6.1 *Loss-of-Coolant-Accident (LOCA)*

The results of the ATRIUM 10XM LOCA analysis are presented in References 28 and 29 as supplemented by Reference 30. The ATRIUM 10XM PCT is 1957°F. The peak local metal water reaction is 1.18% and the maximum core wide metal-water reaction (for hydrogen generation) for a full ATRIUM 10XM core is <1.0%.

The cycle specific ATRIUM 10XM reload fuel PCT was calculated to be 1905°F; therefore, in terms of PCT, the limiting neutronic design used in Reference 29 remains bounding. When compared to the acceptance criteria of less than 17% local cladding oxidation thickness, the local metal-water reaction result remains acceptable.

The LOCA analysis results for the previously loaded ATRIUM-10 fuel are presented in Reference 31 as supplemented by Reference 32.

Analyses and results support the EOD and EOOS conditions listed in Table 1.1. Note: TBVOOS, EOC-RPT-OOS, PLUOOS, and TIPOOS/LPRM out-of-service have no direct influence on the LOCA events.

6.2 *Control Rod Drop Accident (CRDA)*

Plant startup utilizes a bank position withdrawal sequence (BPWS) including rod worth minimization strategies. CRDA evaluation was performed for both A and B sequence startups consistent with the withdrawal sequences specified by TVA. Approved AREVA generic CRDA methodology is described in Reference 33. Subsequent calculations have shown the methodology is applicable to fuel modeled with the CASMO-4/MICROBURN-B2 code system and is applicable to ATRIUM 10XM and ATRIUM-10 fuel.

Maximum deposited fuel rod enthalpy is less than both the current core coolability limit of 280 cal/g and the 230 cal/g limit identified in Standard Review Plan 4.2, Revision 3, Appendix B, Section C, Item 1. Fuel rods conservatively estimated to exceed the existing fuel damage threshold of 170 cal/g are within the UFSAR basis (850 rods). The CRDA analysis results are summarized below.

Maximum dropped control rod worth, mk	9.63
Core average Doppler coefficient, Δk/k/°F	-10.0×10^{-6}
Effective delayed neutron fraction	0.005259
Four-bundle local peaking factor	1.494
Maximum deposited fuel rod enthalpy, cal/g	179.4
Maximum number of rods exceeding 170 cal/g	182

6.3 *Fuel and Equipment Handling Accident*

The fuel handling accident radiological analysis implementing the alternate source term (AST) as approved in Reference 34 was performed with consideration of ATRIUM-10 core source terms. The ATRIUM 10XM source term has been dispositioned relative to those in the AST analysis of record and found to support the same conclusions. Fuel assembly and reactor core isotopic inventories used as input to design basis radiological accident analyses are applicable to all three units (Reference 34). The number of failed fuel rods for the ATRIUM-10 fuel as previously provided to TVA in Reference 35 for use in the AST analysis is unchanged. The number of failed fuel rods for the ATRIUM 10XM fuel is 163, which remains bounded by the analysis of record. No other aspect of utilizing the ATRIUM-10 and ATRIUM 10XM fuel affects the current analysis; therefore, the AST fuel handling accident analysis remains applicable.

6.4 *Fuel Loading Error (Infrequent Event)*

There are two types of fuel loading errors possible in a BWR – the mislocation of a fuel assembly in a core position prescribed to be loaded with another fuel assembly, and the misorientation of a fuel assembly with respect to the control blade. As described in Reference 36, the fuel loading error is characterized as an infrequent event. The acceptance criteria is that the offsite dose consequences due to the event shall not exceed a small fraction of the 10 CFR 50.67 limits.

6.4.1 Mislocated Fuel Bundle

AREVA has performed a bounding fuel mislocation error analysis and has demonstrated continued applicability of the bounding results. The analysis considered the impact of a

mislocated assembly against potential fuel rod failure mechanisms due to increased LHGR and reduced CPR. Based on the analyses, the offsite dose criteria (a small fraction of 10 CFR 50.67) is conservatively satisfied. A dose consequence evaluation is not necessary since no rod approaches the fuel centerline melt or 1% strain limits, and less than 0.1% of the fuel rods are expected to experience boiling transition.

6.4.2 Misoriented Fuel Bundle

AREVA has performed a bounding fuel assembly misorientation analysis. The analysis was performed assuming that the limiting assembly was loaded in the worst orientation (rotated 180°), while simultaneously producing sufficient power to be on the MCPR operating limit as if it were oriented correctly. The analysis demonstrates the small fraction of 10 CFR 50.67 offsite dose criteria is conservatively satisfied. A dose consequence evaluation is not necessary since no rod approaches fuel centerline melt or 1% strain limits, and less than 0.1% of the fuel rods are expected to experience boiling transition.

7.0 Special Analyses

7.1 *ASME Overpressurization Analysis*

This section describes the maximum overpressurization analyses performed to demonstrate compliance with the ASME Boiler and Pressure Vessel Code. The analysis shows that the safety/relief valves have sufficient capacity and performance to prevent the reactor vessel pressure from reaching the safety limit of 110% of the design pressure.

Main steam isolation valve (MSIV) closure, TSV closure, and TCV closure (without bypass) analyses were performed with the AREVA plant simulator code COTRANSA2 (Reference 21) for 102% power and both 81% and 105% flow at the highest cycle exposure. The MSIV closure event is similar to the other steam line valve closure events in that the valve closure results in a rapid pressurization of the core. The increase in pressure causes a decrease in void which in turn causes a rapid increase in power. The turbine bypass valves do not impact the system response and are not modeled in the analysis. The following assumptions were made in the analysis.

- The most critical active component (direct scram on valve position) was assumed to fail. However, scram on high neutron flux and high dome pressure is available.
- To support operation with 1 MSRVOOS, the plant configuration analyzed assumed that one of the lowest setpoint MSRVs was inoperable.
- TSSS insertion times were used.
- The initial dome pressure was set at the maximum allowed by the Technical Specifications plus an additional 5 psi bias, 1070 psia (1055 psig).
- A fast MSIV closure time of 3.0 seconds was used.
- The analytical limit ATWS-RPT setpoint and function were assumed.

Results of the MSIV closure, TCV closure, and TSV closure overpressurization analyses are presented in Table 7.1. Various reactor plant parameters during the limiting MSIV closure event are presented in Figures 7.1 – 7.4. The maximum pressure of 1340 psig occurs in the lower plenum. The maximum dome pressure for the same event is 1304 psig. Results demonstrate the maximum vessel pressure limit of 1375 psig and dome pressure limit of 1325 psig are not exceeded for any analyses.

The peak pressure results include adjustments to address the NRC concerns associated with the void-quality correlation, exposure-dependent thermal conductivity, and Doppler effects.

7.2 *ATWS Event Evaluation*

7.2.1 ATWS Overpressurization Analysis

This section describes analyses performed to demonstrate that the peak vessel pressure for the limiting anticipated transient without scram (ATWS) event is less than the ASME Service Level C limit of 120% of the design pressure (1500 psig). Overpressurization analyses were performed at 100% power at both 81% and 105% flow over the cycle exposure range for both the MSIV closure event and the pressure regulator failure open (PRFO) events. The PRFO event assumes a step decrease in pressure demand such that the pressure control system opens the turbine control and turbine bypass valves. Steam flow demand is assumed to increase to 125% demand (equivalent to 132.6% of rated steam flow) allowing a maximum TCV flow of 106.1% and a maximum bypass system flow of 25.2%. The system pressure decreases until the low pressure setpoint is reached resulting in the closure of the MSIVs. The subsequent pressurization wave collapses core voids, thereby increasing core power.

The following assumptions were made in the analyses.

- The analytical limit ATWS-RPT setpoint and function were assumed.
- To support operation with 1 MSRVOOS, the plant configuration analyzed assumed that one of the lowest setpoint MSRVs was inoperable.
- All scram functions were disabled.
- The initial dome pressure was set to the nominal pressure of 1050 psia.
- A nominal MSIV closure time of 4.0 seconds was used for both events.

Analyses results are presented in Table 7.2. The response of various reactor plant parameters during the limiting PRFO event are shown in Figures 7.5 – 7.8. The maximum lower plenum pressure is 1416 psig and the maximum dome pressure is 1396 psig. The results demonstrate that the ATWS maximum vessel pressure limit of 1500 psig is not exceeded.

The peak pressure results include adjustments to address the NRC concerns associated with the void-quality correlation, exposure-dependent thermal conductivity, and Doppler effects.

7.2.2 Long-Term Evaluation

Fuel design differences may impact the power and pressure excursion experienced during the ATWS event. This in turn may impact the amount of steam discharged to the suppression pool and containment.

Evaluations have been performed to address the impact of each of the fuel types in the BFE1-12 core on the long term ATWS response. The ATRIUM-10 fuel was addressed in Sections 8.2 and 8.3 of Reference 37. The ATRIUM 10XM design is addressed in Section 2.9.2 of Reference 38. Each of these evaluations concludes that the introduction of the respective fuel design does not significantly impact the long term ATWS response (suppression pool temperature and containment pressure) and that the current analysis remains applicable. This conclusion is applicable for the BFE1-12 core design.

7.3 *Standby Liquid Control System*

In the event that the control rod scram function becomes incapable of rendering the core in a shutdown state, the standby liquid control (SLC) system is required to be capable of bringing the reactor from full power to a cold shutdown condition at any time in the core life. The Browns Ferry Unit 1 SLC system is required to be able to inject 720 ppm natural boron equivalent at 70°F into the reactor coolant. AREVA has performed an analysis demonstrating the SLC system meets the required shutdown capability for the cycle. The analysis was performed at a coolant temperature of 366°F, with a boron concentration equivalent to 720 ppm at 68°F*. The temperature of 366°F corresponds to the low pressure permissive for the RHR shutdown cooling suction valves, and represents the maximum reactivity condition with soluble boron in the coolant. The analysis shows the core to be subcritical throughout the cycle by at least 3.49% Δk/k based on the Cycle 11 EOC short window, which is the limiting exposure bound by the short and long Cycle 11 exposure window.

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* TVA Browns Ferry SLC licensing basis documents indicate a minimum of 720 ppm boron at a temperature of 70°F. The AREVA cold analysis basis of 68°F represents a negligible difference and the results are adequate to protect the 70°F licensing basis for the plant.

7.4 *Fuel Criticality*

The spent fuel pool criticality analysis for the fresh ATRIUM 10XM fuel is presented in Reference 39. The ATRIUM-10 and ATRIUM 10XM fuel assemblies identified for the cycle meet the spent fuel storage requirements. The fresh ATRIUM 10XM fuel assemblies will not be stored in the new fuel storage vault.

Table 7.1 ASME Overpressurization Analysis Results*

Event	Peak Neutron Flux (% rated)	Peak Heat Flux (% rated)	Maximum Vessel Pressure Lower-Plenum (psig)	Maximum Dome Pressure (psig)
MSIV closure (102P/105F)	255	127	1340	1304
TSV closure without bypass (102P/105F)	404	135	1333	1293
TCV closure without bypass (102P/105F)	403	135	1338	1298
Pressure Limit	---	---	1375	1325

* The peak pressure results include adjustments to address the NRC concerns associated with the void-quality correlation, exposure-dependent thermal conductivity, and Doppler effects.

Table 7.2 ATWS Overpressurization Analysis Results*

Event	Peak Neutron Flux (% rated)	Peak Heat Flux (% rated)	Maximum Vessel Pressure Lower-Plenum (psig)	Maximum Dome Pressure (psig)
MSIV closure (100P/81F)	253	135	1408	1389
PRFO (100P/81F)	220	143	1416	1396
Pressure Limit	---	---	1500	1500

* The peak pressure results include adjustments to address the NRC concerns associated with the void-quality correlation, exposure-dependent thermal conductivity, and Doppler effects.

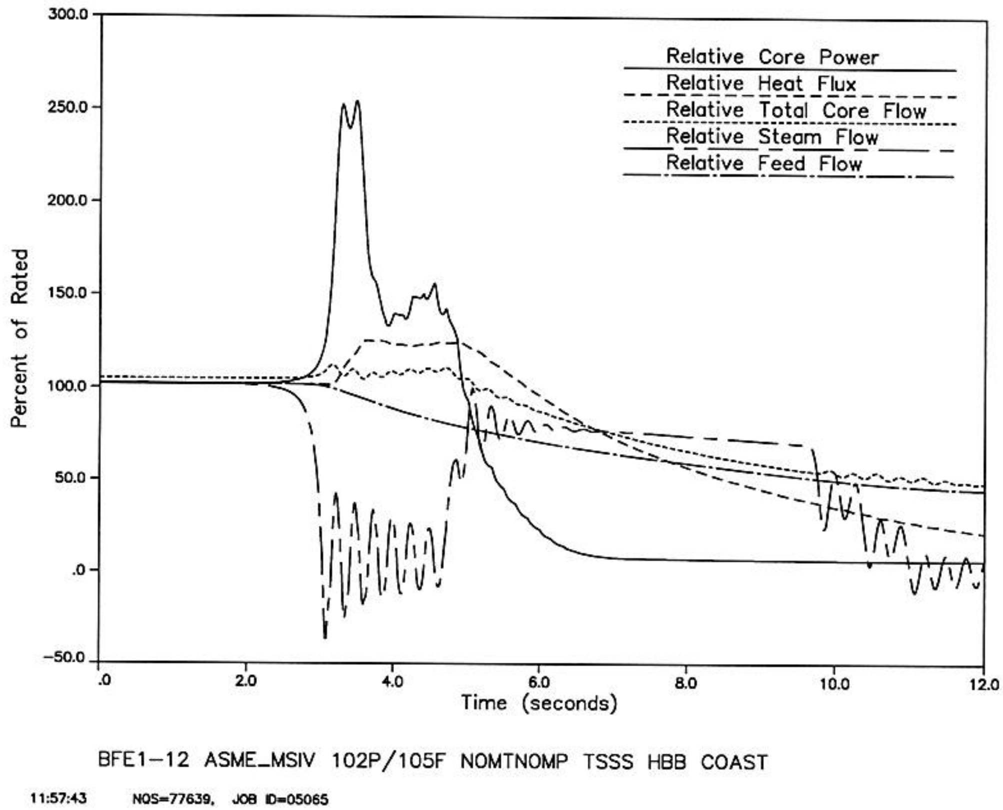

Figure 7.1 MSIV Closure Overpressurization Event at 102P/105F – Key Parameters

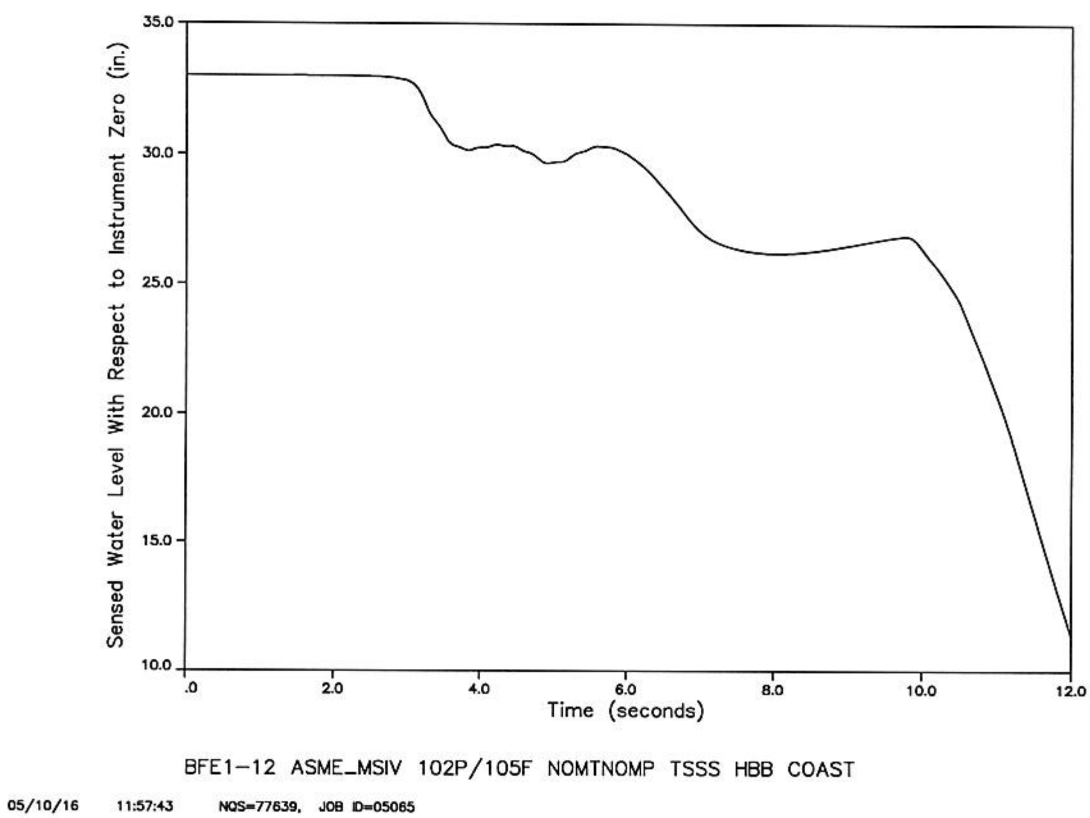

Figure 7.2 MSIV Closure Overpressurization Event at 102P/105F – Sensed Water Level

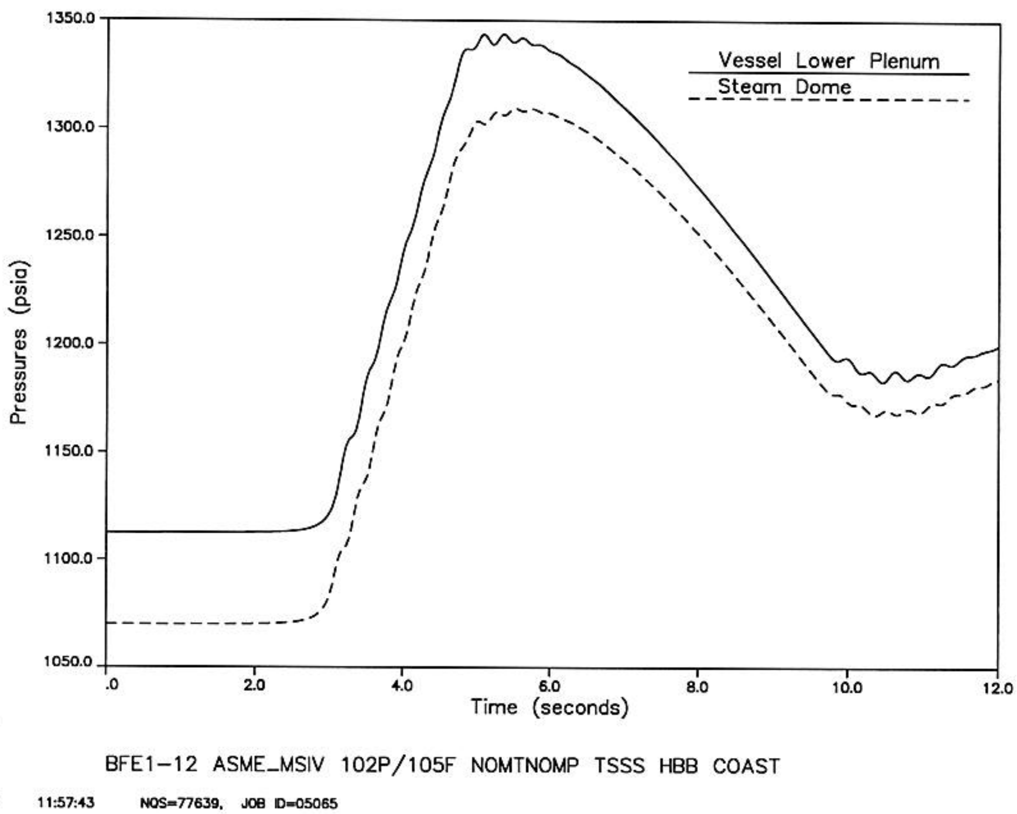

Figure 7.3 MSIV Closure Overpressurization Event at 102P/105F – Vessel Pressures

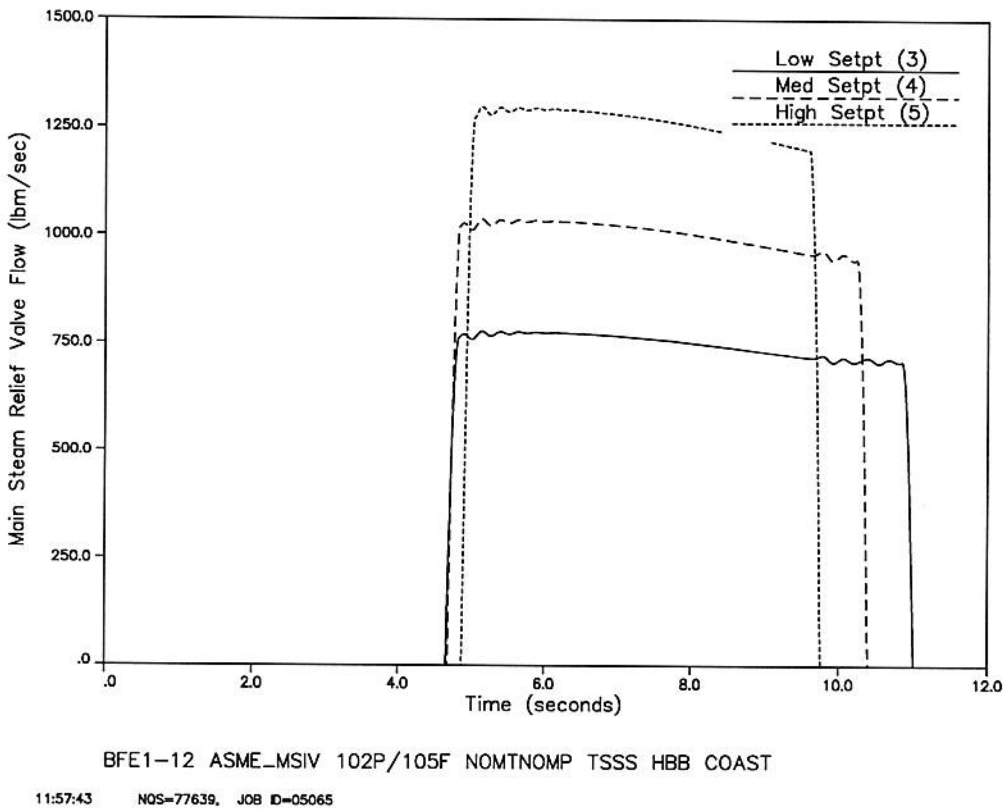

Figure 7.4 MSIV Closure Overpressurization Event at 102P/105F – Safety/Relief Valve Flow Rates

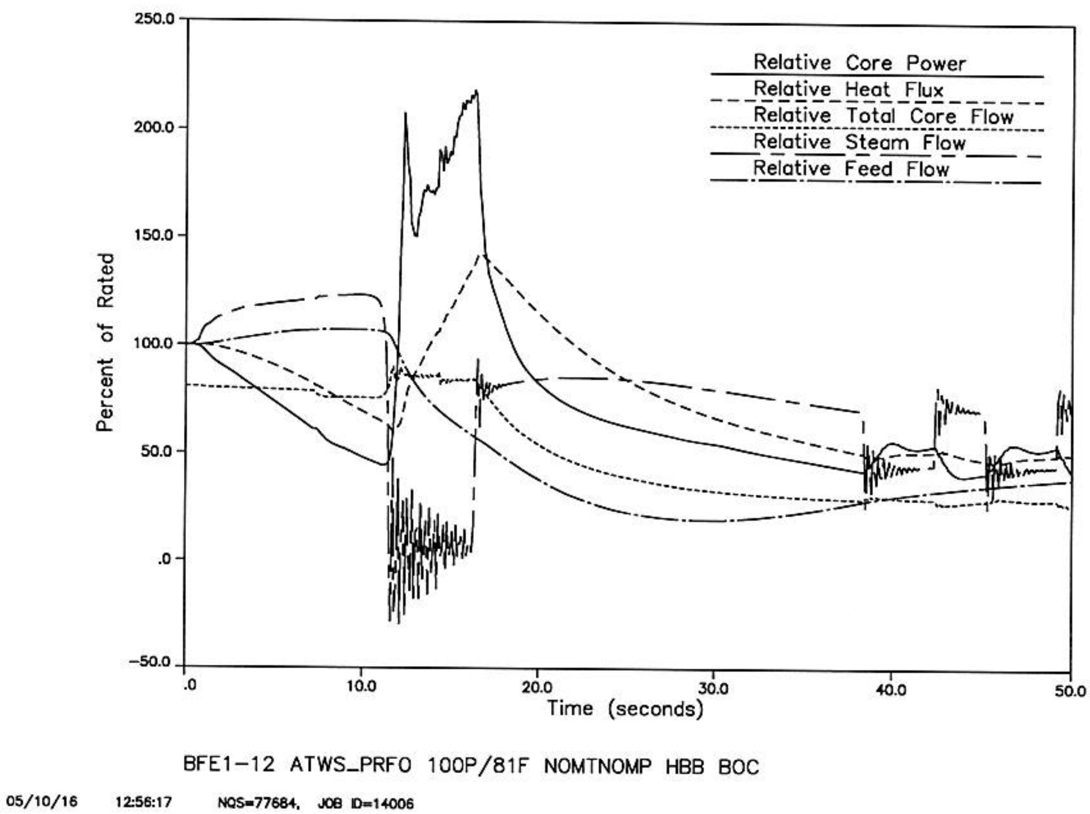

Figure 7.5 PRFO ATWS Overpressurization Event at 100P/81F – Key Parameters

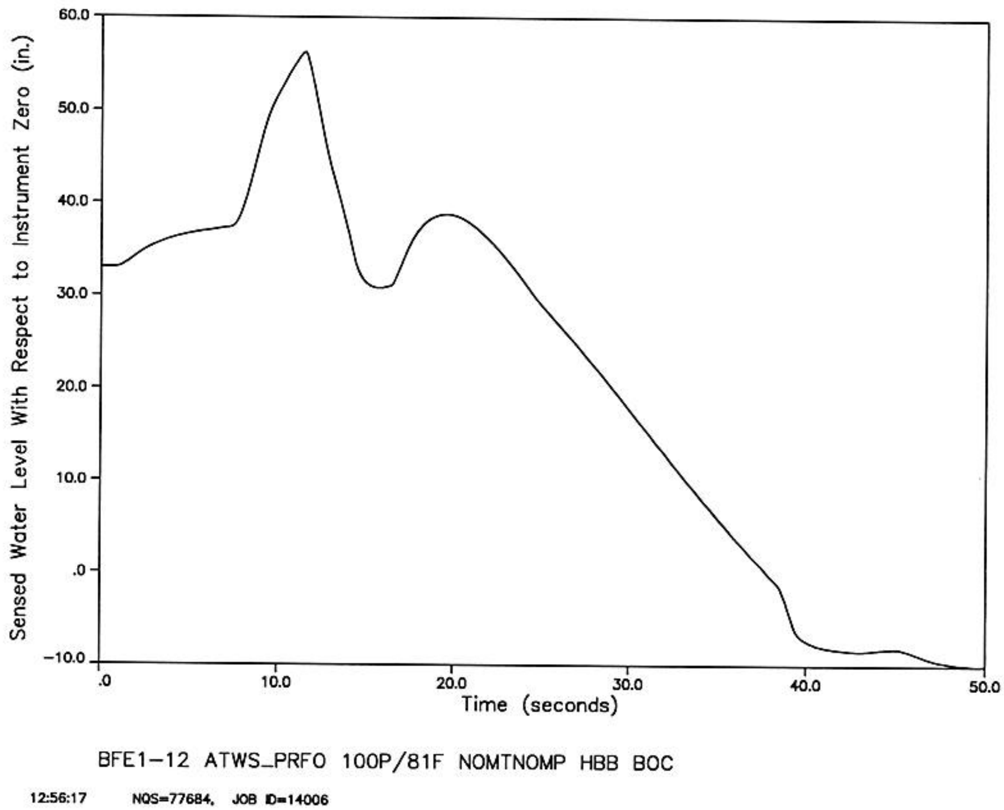

Figure 7.6 PRFO ATWS Overpressurization Event at 100P/81F – Sensed Water Level

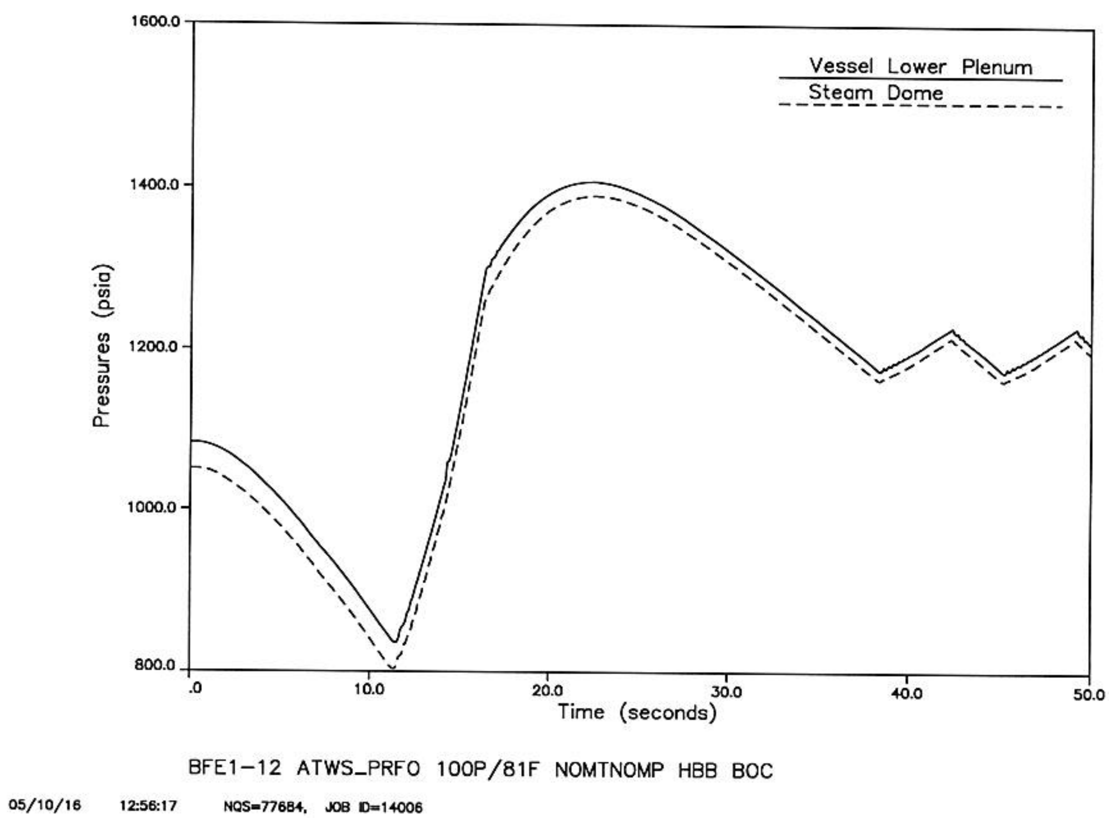

Figure 7.7 PRFO ATWS Overpressurization Event at 100P/81F – Vessel Pressures

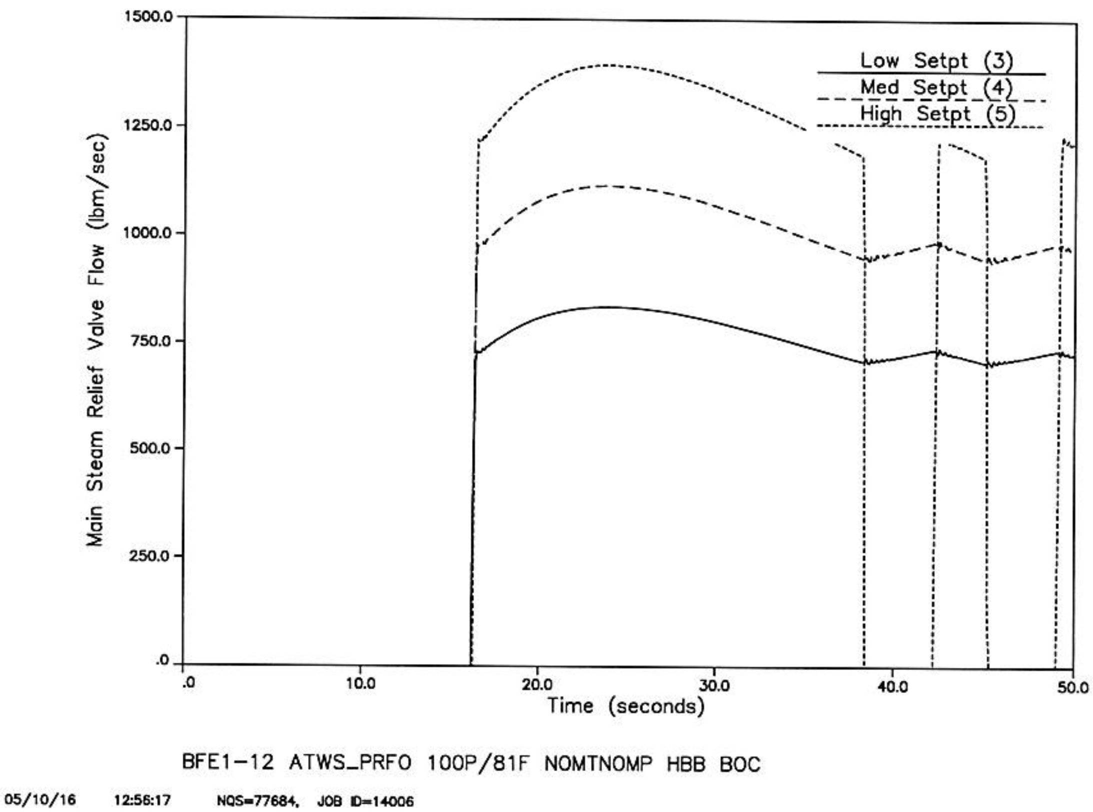

Figure 7.8 PRFO ATWS Overpressurization Event at 100P/81F – Safety/Relief Valve Flow Rates

8.0 Operating Limits and COLR Input

8.1 *MCPR Limits*

Determination of MCPR limits are based on analyses of the limiting AOTs. MCPR operating limits are established such that less than 0.1% of the fuel rods in the core are expected to experience boiling transition during an AOT initiated from rated or off-rated conditions and are based on a TLO SLMCPR of 1.06 and a SLO SLMCPR of 1.08. Exposure-dependent MCPR limits were established to support operation from BOC to NEOC, BOC to EOCLB, and BOC to end of combined FFTR/Coastdown (COAST). MCPR limits are established to support base case operation and the EOOS scenarios presented in Table 1.1.

TLO $MCPR_p$ limits are presented for base case operation and the EOOS conditions in Tables 8.1 – 8.5. Limits are presented for OSS (Table 8.1), NSS (Table 8.2), and TSSS (Table 8.3) insertion times for the exposure ranges considered. Table 8.4 and Table 8.5 presents the TLO $MCPR_p$ limits for the reduced feedwater temperature at startup conditions.

$MCPR_p$ limits for SLO are presented in Table 8.6. They are developed by a combination of the SLO pump seizure results provided in Table 5.9 and the corresponding TLO limits plus 0.02, which accounts for the difference in the TLO and SLO SLMCPR.

$MCPR_f$ limits protect against fuel failures during a postulated slow flow excursion. Fuel limits presented in Table 8.7 are applicable for all cycle exposures and EOOS conditions identified in Table 1.1.

8.2 *LHGR Limits*

The LHGR limits for ATRIUM 10XM and ATRIUM-10 are presented in Table 8.8. Power- and flow-dependent multipliers ($LHGRFAC_p$ and $LHGRFAC_f$) are applied directly to the LHGR limits to protect against fuel melting and overstraining of the cladding during an AOT.

The ATRIUM 10XM $LHGRFAC_p$ multipliers are determined using the RODEX4 thermal-mechanical methodology (Reference 40). $LHGRFAC_p$ multipliers for ATRIUM-10 fuel are determined using the heat flux ratio results from the transient analyses.

$LHGRFAC_p$ multipliers were established to support operation at all cycle exposures for all scram insertion times and for the EOOS conditions identified in Table 1.1 with and without TBVOOS. $LHGRFAC_p$ limits are presented in Table 8.9.

$LHGRFAC_f$ multipliers are established to provide protection against fuel centerline melt and overstraining of the cladding during a postulated slow flow excursion. $LHGRFAC_f$ limits are presented in Table 8.10. $LHGRFAC_f$ multipliers are applicable for all cycle exposures and EOOS conditions identified in Table 1.1.

8.3 *MAPLHGR Limits*

ATRIUM 10XM and ATRIUM-10 MAPLHGR limits are discussed in References 29 and 31, respectively. The TLO limits are presented in Table 8.11. For SLO, a multiplier of 0.85 must be applied to the TLO MAPLHGR limits. Power and flow dependent MAPFAC set-downs are not required; therefore, MAPFAC=1.0.

Table 8.1 TLO $MCPR_p$ Limits for OSS Insertion Times*

Operating Condition	Power (% of rated)	BOC to NEOC		BOC to EOCLB		BOC to End of COAST	
		A10XM	AT10	A10XM	AT10	A10XM	AT10
Base case operation	100.0	1.41	1.47	1.42	1.49	1.44	1.50
	75.0	1.52	1.59	1.52	1.59	1.57	1.62
	65.0	1.58	1.65	1.58	1.65	1.62	1.69
	50.0	1.72	1.84	1.72	1.84	1.79	1.92
	50.0	1.79	1.95	1.79	1.95	1.80	1.95
	40.0	1.93	2.07	1.93	2.07	2.02	2.17
	30.0	2.21	2.39	2.21	2.39	2.33	2.51
	30.0 at > 50%F	2.46	2.41	2.46	2.41	2.55	2.51
	25.0 at > 50%F	2.48	2.63	2.48	2.63	2.72	2.74
	30.0 at ≤ 50%F	2.21	2.39	2.21	2.39	2.33	2.51
	25.0 at ≤ 50%F	2.39	2.57	2.39	2.57	2.50	2.66
FHOOS	100.0	1.43	1.49	1.44	1.50	---	---
	75.0	1.56	1.62	1.57	1.62	---	---
	65.0	1.62	1.69	1.62	1.69	---	---
	50.0	1.79	1.92	1.79	1.92	---	---
	50.0	1.80	1.95	1.80	1.95	---	---
	40.0	2.02	2.17	2.02	2.17	---	---
	30.0	2.33	2.51	2.33	2.51	---	---
	30.0 at > 50%F	2.55	2.51	2.55	2.51	---	---
	25.0 at > 50%F	2.72	2.74	2.72	2.74	---	---
	30.0 at ≤ 50%F	2.33	2.51	2.33	2.51	---	---
	25.0 at ≤ 50%F	2.50	2.66	2.50	2.66	---	---

* Limits support operation with or without EOC-RPT-OOS and any combination of 1 MSRVOOS, up to 2 TIPOOS (or the equivalent number of TIP channels), and up to 50% of the LPRMs out-of-service. BOC to End of COAST limits also support operation with FFTR/FHOOS which bounds operation with feedwater heaters in-service.

Table 8.2 TLO $MCPR_p$ Limits for NSS Insertion Times*

Operating Condition	Power (% of rated)	BOC to NEOC		BOC to EOCLB		BOC to End of COAST	
		A10XM	AT10	A10XM	AT10	A10XM	AT10
Base case operation	100.0	1.42	1.49	1.43	1.50	1.45	1.52
	75.0	1.53	1.60	1.53	1.60	1.57	1.64
	65.0	1.59	1.66	1.59	1.66	1.63	1.73
	50.0	1.74	1.87	1.74	1.87	---	---
	50.0	1.79	1.95	1.80	1.95	1.82	1.96
	40.0	1.95	2.10	1.95	2.10	2.05	2.21
	30.0	2.23	2.43	2.23	2.43	2.35	2.55
	30.0 at > 50%F	2.46	2.43	2.46	2.43	2.55	2.55
	25.0 at > 50%F	2.48	2.63	2.48	2.63	2.72	2.74
	30.0 at ≤ 50%F	2.23	2.43	2.23	2.43	2.35	2.55
	25.0 at ≤ 50%F	2.39	2.57	2.39	2.57	2.50	2.66
TBVOOS	100.0	1.46	1.55	1.47	1.56	1.48	1.57
	75.0	1.57	1.66	1.57	1.66	1.61	1.68
	65.0	1.63	1.72	1.63	1.72	1.67	1.76
	50.0	1.76	1.88	1.76	1.88	---	---
	50.0	1.79	1.95	1.80	1.95	1.82	1.96
	40.0	1.95	2.11	1.95	2.11	2.05	2.21
	30.0	2.23	2.43	2.23	2.43	2.35	2.55
	30.0 at > 50%F	2.91	3.01	2.91	3.01	3.01	3.10
	25.0 at > 50%F	3.15	3.33	3.15	3.33	3.24	3.42
	30.0 at ≤ 50%F	2.60	2.82	2.60	2.82	2.72	2.93
	25.0 at ≤ 50%F	2.97	3.19	2.97	3.19	3.11	3.33
FHOOS	100.0	1.45	1.51	1.45	1.52	---	---
	75.0	1.56	1.64	1.57	1.64	---	---
	65.0	1.63	1.73	1.63	1.73	---	---
	50.0	---	---	---	---	---	---
	50.0	1.82	1.96	1.82	1.96	---	---
	40.0	2.05	2.21	2.05	2.21	---	---
	30.0	2.35	2.55	2.35	2.55	---	---
	30.0 at > 50%F	2.55	2.55	2.55	2.55	---	---
	25.0 at > 50%F	2.72	2.74	2.72	2.74	---	---
	30.0 at ≤ 50%F	2.35	2.55	2.35	2.55	---	---
	25.0 at ≤ 50%F	2.50	2.66	2.50	2.66	---	---
PLUOOS	100.0	1.42	1.49	1.43	1.50	1.45	1.52
	75.0	1.53	1.60	1.53	1.60	1.57	1.64
	65.0	1.71	1.86	1.72	1.86	1.72	1.86
	50.0	---	---	---	---	---	---
	50.0	1.79	1.95	1.81	1.95	1.82	1.96
	40.0	1.95	2.10	1.95	2.10	2.05	2.21
	30.0	2.23	2.43	2.23	2.43	2.35	2.55
	30.0 at > 50%F	2.46	2.43	2.46	2.43	2.55	2.55
	25.0 at > 50%F	2.48	2.63	2.48	2.63	2.72	2.74
	30.0 at ≤ 50%F	2.23	2.43	2.23	2.43	2.35	2.55
	25.0 at ≤ 50%F	2.39	2.57	2.39	2.57	2.50	2.66

* Limits support operation with or without EOC-RPT-OOS and any combination of 1 MSRVOOS, up to 2 TIPOOS (or the equivalent number of TIP channels), and up to 50% of the LPRMs out-of-service. BOC to End of COAST limits also support operation with FFTR/FHOOS which bounds operation with feedwater heaters in-service.

Table 8.2 TLO $MCPR_p$ Limits for
NSS Insertion Times
(Continued)

Operating Condition	Power (% of rated)	BOC to NEOC		BOC to EOCLB		BOC to End of COAST	
		A10XM	AT10	A10XM	AT10	A10XM	AT10
TBVOOS and FHOOS	100.0	1.48	1.57	1.48	1.57	---	---
	75.0	1.60	1.68	1.61	1.68	---	---
	65.0	1.67	1.76	1.67	1.76	---	---
	50.0	---	---	---	---	---	---
	50.0	1.82	1.96	1.82	1.96	---	---
	40.0	2.05	2.21	2.05	2.21	---	---
	30.0	2.35	2.55	2.35	2.55	---	---
	30.0 at > 50%F	3.01	3.10	3.01	3.10	---	---
	25.0 at > 50%F	3.24	3.42	3.24	3.42	---	---
	30.0 at ≤ 50%F	2.72	2.93	2.72	2.93	---	---
	25.0 at ≤ 50%F	3.11	3.33	3.11	3.33	---	---
TBVOOS and PLUOOS	100.0	1.46	1.55	1.47	1.56	1.48	1.57
	75.0	1.57	1.66	1.57	1.66	1.61	1.68
	65.0	1.71	1.86	1.72	1.86	1.72	1.86
	50.0	---	---	---	---	---	---
	50.0	1.79	1.95	1.81	1.95	1.82	1.96
	40.0	1.95	2.11	1.95	2.11	2.05	2.21
	30.0	2.23	2.43	2.23	2.43	2.35	2.55
	30.0 at > 50%F	2.91	3.01	2.91	3.01	3.01	3.10
	25.0 at > 50%F	3.15	3.33	3.15	3.33	3.24	3.42
	30.0 at ≤ 50%F	2.60	2.82	2.60	2.82	2.72	2.93
	25.0 at ≤ 50%F	2.97	3.19	2.97	3.19	3.11	3.33
FHOOS and PLUOOS	100.0	1.45	1.51	1.45	1.52	---	---
	75.0	1.56	1.64	1.57	1.64	---	---
	65.0	1.71	1.86	1.72	1.86	---	---
	50.0	---	---	---	---	---	---
	50.0	1.82	1.96	1.82	1.96	---	---
	40.0	2.05	2.21	2.05	2.21	---	---
	30.0	2.35	2.55	2.35	2.55	---	---
	30.0 at > 50%F	2.55	2.55	2.55	2.55	---	---
	25.0 at > 50%F	2.72	2.74	2.72	2.74	---	---
	30.0 at ≤ 50%F	2.35	2.55	2.35	2.55	---	---
	25.0 at ≤ 50%F	2.50	2.66	2.50	2.66	---	---
TBVOOS, FHOOS, and PLUOOS	100.0	1.48	1.57	1.48	1.57	---	---
	75.0	1.60	1.68	1.61	1.68	---	---
	65.0	1.71	1.86	1.72	1.86	---	---
	50.0	---	---	---	---	---	---
	50.0	1.82	1.96	1.82	1.96	---	---
	40.0	2.05	2.21	2.05	2.21	---	---
	30.0	2.35	2.55	2.35	2.55	---	---
	30.0 at > 50%F	3.01	3.10	3.01	3.10	---	---
	25.0 at > 50%F	3.24	3.42	3.24	3.42	---	---
	30.0 at ≤ 50%F	2.72	2.93	2.72	2.93	---	---
	25.0 at ≤ 50%F	3.11	3.33	3.11	3.33	---	---

Table 8.3 TLO $MCPR_p$ Limits for TSSS Insertion Times*

Operating Condition	Power (% of rated)	BOC to NEOC		BOC to EOCLB		BOC to End of COAST	
		A10XM	AT10	A10XM	AT10	A10XM	AT10
Base case operation	100.0	1.44	1.51	1.44	1.51	1.46	1.54
	75.0	1.54	1.61	1.54	1.61	1.57	1.66
	65.0	1.60	1.70	1.60	1.70	1.64	1.77
	50.0	1.77	1.91	1.77	1.91	---	---
	50.0	1.80	1.96	1.82	1.96	1.84	1.99
	40.0	1.98	2.14	1.98	2.14	2.07	2.24
	30.0	2.25	2.47	2.25	2.47	2.37	2.59
	30.0 at > 50%F	2.46	2.47	2.46	2.47	2.55	2.59
	25.0 at > 50%F	2.48	2.63	2.48	2.63	2.72	2.74
	30.0 at ≤ 50%F	2.25	2.47	2.25	2.47	2.37	2.59
	25.0 at ≤ 50%F	2.39	2.57	2.39	2.57	2.50	2.66
TBVOOS	100.0	1.47	1.57	1.48	1.57	1.49	1.61
	75.0	1.58	1.67	1.58	1.67	1.61	1.70
	65.0	1.64	1.73	1.64	1.73	1.68	1.78
	50.0	1.78	1.92	1.78	1.92	---	---
	50.0	1.80	1.96	1.82	1.96	1.85	2.00
	40.0	1.98	2.15	1.98	2.15	2.08	2.24
	30.0	2.26	2.47	2.26	2.47	2.37	2.59
	30.0 at > 50%F	2.91	3.01	2.91	3.01	3.01	3.10
	25.0 at > 50%F	3.15	3.33	3.15	3.33	3.24	3.42
	30.0 at ≤ 50%F	2.60	2.82	2.60	2.82	2.72	2.93
	25.0 at ≤ 50%F	2.97	3.19	2.97	3.19	3.11	3.33
FHOOS	100.0	1.46	1.53	1.46	1.53	---	---
	75.0	1.57	1.66	1.57	1.66	---	---
	65.0	1.64	1.77	1.64	1.77	---	---
	50.0	---	---	---	---	---	---
	50.0	1.84	1.99	1.84	1.99	---	---
	40.0	2.07	2.24	2.07	2.24	---	---
	30.0	2.37	2.59	2.37	2.59	---	---
	30.0 at > 50%F	2.55	2.59	2.55	2.59	---	---
	25.0 at > 50%F	2.72	2.74	2.72	2.74	---	---
	30.0 at ≤ 50%F	2.37	2.59	2.37	2.59	---	---
	25.0 at ≤ 50%F	2.50	2.66	2.50	2.66	---	---
PLUOOS	100.0	1.44	1.51	1.44	1.51	1.46	1.54
	75.0	1.54	1.61	1.54	1.61	1.57	1.66
	65.0	1.72	1.87	1.75	1.87	1.75	1.88
	50.0	---	---	---	---	---	---
	50.0	1.81	1.96	1.82	1.96	1.84	1.99
	40.0	1.98	2.14	1.98	2.14	2.07	2.24
	30.0	2.25	2.47	2.25	2.47	2.37	2.59
	30.0 at > 50%F	2.46	2.47	2.46	2.47	2.55	2.59
	25.0 at > 50%F	2.48	2.63	2.48	2.63	2.72	2.74
	30.0 at ≤ 50%F	2.25	2.47	2.25	2.47	2.37	2.59
	25.0 at ≤ 50%F	2.39	2.57	2.39	2.57	2.50	2.66

* Limits support operation with or without EOC-RPT-OOS and any combination of 1 MSRVOOS, up to 2 TIPOOS (or the equivalent number of TIP channels), and up to 50% of the LPRMs out-of-service. BOC to End of COAST limits also support operation with FFTR/FHOOS which bounds operation with feedwater heaters in-service.

Table 8.3 TLO $MCPR_p$ Limits for TSSS Insertion Times
(Continued)

Operating Condition	Power (% of rated)	BOC to NEOC		BOC to EOCLB		BOC to End of COAST	
		A10XM	AT10	A10XM	AT10	A10XM	AT10
TBVOOS and FHOOS	100.0	1.49	1.58	1.49	1.58	---	---
	75.0	1.61	1.70	1.61	1.70	---	---
	65.0	1.68	1.78	1.68	1.78	---	---
	50.0	---	---	---	---	---	---
	50.0	1.85	2.00	1.85	2.00	---	---
	40.0	2.08	2.24	2.08	2.24	---	---
	30.0	2.37	2.59	2.37	2.59	---	---
	30.0 at > 50%F	3.01	3.10	3.01	3.10	---	---
	25.0 at > 50%F	3.24	3.42	3.24	3.42	---	---
	30.0 at ≤ 50%F	2.72	2.93	2.72	2.93	---	---
	25.0 at ≤ 50%F	3.11	3.33	3.11	3.33	---	---
TBVOOS and PLUOOS	100.0	1.47	1.57	1.48	1.57	1.49	1.61
	75.0	1.58	1.67	1.58	1.67	1.61	1.70
	65.0	1.72	1.87	1.75	1.87	1.75	1.88
	50.0	---	---	---	---	---	---
	50.0	1.81	1.96	1.82	1.96	1.85	2.00
	40.0	1.98	2.15	1.98	2.15	2.08	2.24
	30.0	2.26	2.47	2.26	2.47	2.37	2.59
	30.0 at > 50%F	2.91	3.01	2.91	3.01	3.01	3.10
	25.0 at > 50%F	3.15	3.33	3.15	3.33	3.24	3.42
	30.0 at ≤ 50%F	2.60	2.82	2.60	2.82	2.72	2.93
	25.0 at ≤ 50%F	2.97	3.19	2.97	3.19	3.11	3.33
FHOOS and PLUOOS	100.0	1.46	1.53	1.46	1.53	---	---
	75.0	1.57	1.66	1.57	1.66	---	---
	65.0	1.72	1.87	1.75	1.87	---	---
	50.0	---	---	---	---	---	---
	50.0	1.84	1.99	1.84	1.99	---	---
	40.0	2.07	2.24	2.07	2.24	---	---
	30.0	2.37	2.59	2.37	2.59	---	---
	30.0 at > 50%F	2.55	2.59	2.55	2.59	---	---
	25.0 at > 50%F	2.72	2.74	2.72	2.74	---	---
	30.0 at ≤ 50%F	2.37	2.59	2.37	2.59	---	---
	25.0 at ≤ 50%F	2.50	2.66	2.50	2.66	---	---
TBVOOS, FHOOS, and PLUOOS	100.0	1.49	1.58	1.49	1.58	---	---
	75.0	1.61	1.70	1.61	1.70	---	---
	65.0	1.72	1.87	1.75	1.87	---	---
	50.0	---	---	---	---	---	---
	50.0	1.85	2.00	1.85	2.00	---	---
	40.0	2.08	2.24	2.08	2.24	---	---
	30.0	2.37	2.59	2.37	2.59	---	---
	30.0 at > 50%F	3.01	3.10	3.01	3.10	---	---
	25.0 at > 50%F	3.24	3.42	3.24	3.42	---	---
	30.0 at ≤ 50%F	2.72	2.93	2.72	2.93	---	---
	25.0 at ≤ 50%F	3.11	3.33	3.11	3.33	---	---

**Table 8.4 TLO $MCPR_p$ Limits for
Reduced Feedwater Temperature at Startup
NSS Insertion Times***

Operating Condition	Power (% of rated)	BOC to NEOC		BOC to EOCLB		BOC to End of COAST	
		A10XM	AT10	A10XM	AT10	A10XM	AT10
Startup FHOOS 1 TBVIS†	100.0	1.45	1.51	1.45	1.52	1.45	1.52
	75.0	1.56	1.64	1.57	1.64	1.57	1.64
	65.0	1.71	1.86	1.72	1.86	1.72	1.86
	50.0	---	---	---	---	---	---
	50.0	1.99	2.15	1.99	2.15	1.99	2.15
	40.0	2.28	2.45	2.28	2.45	2.28	2.45
	30.0	2.65	2.86	2.65	2.86	2.65	2.86
	30.0 at > 50%F	2.79	2.86	2.79	2.86	2.79	2.86
	25.0 at > 50%F	3.02	3.02	3.02	3.02	3.02	3.02
	30.0 at ≤ 50%F	2.65	2.86	2.65	2.86	2.65	2.86
	25.0 at ≤ 50%F	2.77	2.93	2.77	2.93	2.77	2.93
Startup FHOOS 1 TBVOOS†	100.0	1.48	1.57	1.48	1.57	1.48	1.57
	75.0	1.60	1.68	1.61	1.68	1.61	1.68
	65.0	1.71	1.86	1.72	1.86	1.72	1.86
	50.0	---	---	---	---	---	---
	50.0	1.99	2.15	1.99	2.15	1.99	2.15
	40.0	2.28	2.45	2.28	2.45	2.28	2.45
	30.0	2.65	2.86	2.65	2.86	2.65	2.86
	30.0 at > 50%F	3.18	3.25	3.18	3.25	3.18	3.25
	25.0 at > 50%F	3.40	3.58	3.40	3.58	3.40	3.58
	30.0 at ≤ 50%F	2.91	3.10	2.91	3.10	2.91	3.10
	25.0 at ≤ 50%F	3.32	3.55	3.32	3.55	3.32	3.55

* Limits support operation with or without EOC-RPT-OOS and any combination of 1 MSRVOOS, up to 2 TIPOOS (or the equivalent number of TIP channels), and up to 50% of the LPRMs out-of-service.

† TBVIS limits are applicable for all EOOS scenarios presented in Table 1.1 except those that include TBVOOS. TBVOOS limits are applicable for all EOOS scenarios presented in Table 1.1. Startup FHOOS 1 temperatures are presented in Item 6.6.1 of Reference 20.

Table 8.4 TLO $MCPR_p$ Limits for Reduced Feedwater Temperature at Startup NSS Insertion Times* *(Continued)*

Operating Condition	Power (% of rated)	BOC to NEOC		BOC to EOCLB		BOC to End of COAST	
		A10XM	AT10	A10XM	AT10	A10XM	AT10
Startup FHOOS 2 TBVIS†	100.0	1.45	1.51	1.45	1.52	1.45	1.52
	75.0	1.56	1.64	1.57	1.64	1.57	1.64
	65.0	1.71	1.86	1.72	1.86	1.72	1.86
	50.0	---	---	---	---	---	---
	50.0	2.00	2.16	2.00	2.16	2.00	2.16
	40.0	2.29	2.46	2.29	2.46	2.29	2.46
	30.0	2.67	2.88	2.67	2.88	2.67	2.88
	30.0 at > 50%F	2.80	2.88	2.80	2.88	2.80	2.88
	25.0 at > 50%F	3.05	3.04	3.05	3.04	3.05	3.04
	30.0 at ≤ 50%F	2.67	2.88	2.67	2.88	2.67	2.88
	25.0 at ≤ 50%F	2.79	2.95	2.79	2.95	2.79	2.95
Startup FHOOS 2 TBVOOS†	100.0	1.48	1.57	1.48	1.57	1.48	1.57
	75.0	1.60	1.68	1.61	1.68	1.61	1.68
	65.0	1.71	1.86	1.72	1.86	1.72	1.86
	50.0	---	---	---	---	---	---
	50.0	2.00	2.16	2.00	2.16	2.00	2.16
	40.0	2.29	2.46	2.29	2.46	2.29	2.46
	30.0	2.67	2.88	2.67	2.88	2.67	2.88
	30.0 at > 50%F	3.19	3.26	3.19	3.26	3.19	3.26
	25.0 at > 50%F	3.41	3.59	3.41	3.59	3.41	3.59
	30.0 at ≤ 50%F	2.92	3.12	2.92	3.12	2.92	3.12
	25.0 at ≤ 50%F	3.33	3.56	3.33	3.56	3.33	3.56

* Limits support operation with or without EOC-RPT-OOS and any combination of 1 MSRVOOS, up to 2 TIPOOS (or the equivalent number of TIP channels), and up to 50% of the LPRMs out-of-service.

† TBVIS limits are applicable for all EOOS scenarios presented in Table 1.1 except those that include TBVOOS. TBVOOS limits are applicable for all EOOS scenarios presented in Table 1.1. Startup FHOOS 2 temperatures represent an additional 5°F reduction from the values shown in Item 6.6.1 of Reference 20.

Table 8.5 TLO $MCPR_p$ Limits for Reduced Feedwater Temperature at Startup TSSS Insertion Times*

Operating Condition	Power (% of rated)	BOC to NEOC		BOC to EOCLB		BOC to End of COAST	
		A10XM	AT10	A10XM	AT10	A10XM	AT10
Startup FHOOS 1 TBVIS†	100.0	1.46	1.53	1.46	1.53	1.46	1.54
	75.0	1.57	1.66	1.57	1.66	1.57	1.66
	65.0	1.72	1.87	1.75	1.87	1.75	1.88
	50.0	---	---	---	---	---	---
	50.0	2.02	2.18	2.02	2.18	2.02	2.18
	40.0	2.31	2.48	2.31	2.48	2.31	2.48
	30.0	2.67	2.90	2.67	2.90	2.67	2.90
	30.0 at > 50%F	2.79	2.90	2.79	2.90	2.79	2.90
	25.0 at > 50%F	3.02	3.02	3.02	3.02	3.02	3.02
	30.0 at ≤ 50%F	2.67	2.90	2.67	2.90	2.67	2.90
	25.0 at ≤ 50%F	2.77	2.93	2.77	2.93	2.77	2.93
Startup FHOOS 1 TBVOOS†	100.0	1.49	1.58	1.49	1.58	1.49	1.61
	75.0	1.61	1.70	1.61	1.70	1.61	1.70
	65.0	1.72	1.87	1.75	1.87	1.75	1.88
	50.0	---	---	---	---	---	---
	50.0	2.02	2.18	2.02	2.18	2.02	2.18
	40.0	2.31	2.48	2.31	2.48	2.31	2.48
	30.0	2.67	2.90	2.67	2.90	2.67	2.90
	30.0 at > 50%F	3.18	3.25	3.18	3.25	3.18	3.25
	25.0 at > 50%F	3.40	3.58	3.40	3.58	3.40	3.58
	30.0 at ≤ 50%F	2.91	3.10	2.91	3.10	2.91	3.10
	25.0 at ≤ 50%F	3.32	3.55	3.32	3.55	3.32	3.55

* Limits support operation with or without EOC-RPT-OOS and any combination of 1 MSRVOOS, up to 2 TIPOOS (or the equivalent number of TIP channels), and up to 50% of the LPRMs out-of-service.

† TBVIS limits are applicable for all EOOS scenarios presented in Table 1.1 except those that include TBVOOS. TBVOOS limits are applicable for all EOOS scenarios presented in Table 1.1. Startup FHOOS 1 temperatures are presented in Item 6.6.1 of Reference 20.

Table 8.5 TLO $MCPR_p$ Limits for Reduced Feedwater Temperature at Startup TSSS Insertion Times* *(Continued)*

Operating Condition	Power (% of rated)	BOC to NEOC		BOC to EOCLB		BOC to End of COAST	
		A10XM	AT10	A10XM	AT10	A10XM	AT10
Startup FHOOS 2 TBVIS†	100.0	1.46	1.53	1.46	1.53	1.46	1.54
	75.0	1.57	1.66	1.57	1.66	1.57	1.66
	65.0	1.72	1.87	1.75	1.87	1.75	1.88
	50.0	---	---	---	---	---	---
	50.0	2.03	2.19	2.03	2.19	2.03	2.19
	40.0	2.32	2.50	2.32	2.50	2.32	2.50
	30.0	2.69	2.92	2.69	2.92	2.69	2.92
	30.0 at > 50%F	2.80	2.92	2.80	2.92	2.80	2.92
	25.0 at > 50%F	3.05	3.04	3.05	3.04	3.05	3.04
	30.0 at ≤ 50%F	2.69	2.92	2.69	2.92	2.69	2.92
	25.0 at ≤ 50%F	2.79	2.95	2.79	2.95	2.79	2.95
Startup FHOOS 2 TBVOOS†	100.0	1.49	1.58	1.49	1.58	1.49	1.61
	75.0	1.61	1.70	1.61	1.70	1.61	1.70
	65.0	1.72	1.87	1.75	1.87	1.75	1.88
	50.0	---	---	---	---	---	---
	50.0	2.03	2.19	2.03	2.19	2.03	2.19
	40.0	2.32	2.50	2.32	2.50	2.32	2.50
	30.0	2.69	2.92	2.69	2.92	2.69	2.92
	30.0 at > 50%F	3.19	3.26	3.19	3.26	3.19	3.26
	25.0 at > 50%F	3.41	3.59	3.41	3.59	3.41	3.59
	30.0 at ≤ 50%F	2.92	3.12	2.92	3.12	2.92	3.12
	25.0 at ≤ 50%F	3.33	3.56	3.33	3.56	3.33	3.56

* Limits support operation with or without EOC-RPT-OOS and any combination of 1 MSRVOOS, up to 2 TIPOOS (or the equivalent number of TIP channels), and up to 50% of the LPRMs out-of-service.

† TBVIS limits are applicable for all EOOS scenarios presented in Table 1.1 except those that include TBVOOS. TBVOOS limits are applicable for all EOOS scenarios presented in Table 1.1. Startup FHOOS 2 temperatures represent an additional 5°F reduction from the values shown in Item 6.6.1 of Reference 20.

Table 8.6 SLO $MCPR_p$ Limits for All Scram Speeds*

Operating Condition	Power (% of rated)	BOC to End of COAST	
		A10XM	AT10
RCPOOS FHOOS	100.0	2.02	2.01
	50.0	2.02	2.01
	40.0	2.09	2.26
	30.0	2.39	2.61
	30.0 at > 50%F	2.57	2.61
	25.0 at > 50%F	2.74	2.76
	30.0 at ≤ 50%F	2.39	2.61
	25.0 at ≤ 50%F	2.52	2.68
RCPOOS TBVOOS PLUOOS FHOOS	100.0	2.02	2.02
	50.0	2.02	2.02
	40.0	2.10	2.26
	30.0	2.39	2.61
	30.0 at > 50%F	3.03	3.12
	25.0 at > 50%F	3.26	3.44
	30.0 at ≤ 50%F	2.74	2.95
	25.0 at ≤ 50%F	3.13	3.35
RCPOOS TBVOOS FHOOS1	100.0	2.04	2.20
	50.0	2.04	2.20
	40.0	2.33	2.50
	30.0	2.69	2.92
	30.0 at > 50%F	3.20	3.27
	25.0 at > 50%F	3.42	3.60
	30.0 at ≤ 50%F	2.93	3.12
	25.0 at ≤ 50%F	3.34	3.57
RCPOOS TBVOOS FHOOS2	100.0	2.05	2.21
	50.0	2.05	2.21
	40.0	2.34	2.52
	30.0	2.71	2.94
	30.0 at > 50%F	3.21	3.28
	25.0 at > 50%F	3.43	3.61
	30.0 at ≤ 50%F	2.94	3.14
	25.0 at ≤ 50%F	3.35	3.58

* Thermal limits are developed by combining the SLO pump seizure event with the corresponding TLO limit set plus 0.02, which accounts for the difference in TLO and SLO SLMCPR. RCPOOS thermal limits are only valid up to 50% core power, 50% core flow, and an active recirculation drive flow of 17.73 Mlb/hr.

Table 8.7 MCPR$_f$ Limits for all Fuel Types

Core Flow (% of rated)	MCPR$_f$
30.0	1.61
78.0	1.28
107.0	1.28

Table 8.8 Steady-State LHGR Limits

Peak Pellet Exposure (GWd/MTU)	ATRIUM 10XM LHGR (kW/ft)	ATRIUM-10 LHGR (kW/ft)
0.0	14.1	13.4
18.9	14.1	13.4
74.4	7.4	7.1

Table 8.9 LHGRFAC$_p$ Multipliers*

EOOS Condition	Power (% rated)	Base case operation (TBVIS)† LHGRFAC$_p$		TBVOOS‡ LHGRFAC$_p$	
		A10XM	AT10	A10XM	AT10
Nominal operation and FHOOS§	100.0	1.00	1.00	0.97	0.90
	75.0	--	0.80	--	0.78
	30.0	0.69	0.60	0.67	0.60
	30.0 at > 50%F	0.53	0.60	0.43	0.48
	25.0 at > 50%F	0.49	0.56	0.38	0.44
	30.0 at ≤ 50%F	0.53	0.60	0.52	0.52
	25.0 at ≤ 50%F	0.52	0.58	0.45	0.48
Startup FHOOS 1§	100.0	1.00	1.00	0.97	0.90
	75.0	--	0.80	--	0.78
	30.0	0.59	0.55	0.57	0.55
	30.0 at > 50%F	0.47	0.55	0.41	0.46
	25.0 at > 50%F	0.43	0.51	0.35	0.42
	30.0 at ≤ 50%F	0.48	0.55	0.46	0.50
	25.0 at ≤ 50%F	0.46	0.53	0.40	0.45
Startup FHOOS 2§	100.0	1.00	1.00	0.97	0.90
	75.0	--	0.80	--	0.78
	30.0	0.58	0.55	0.57	0.55
	30.0 at > 50%F	0.47	0.55	0.41	0.46
	25.0 at > 50%F	0.43	0.50	0.35	0.42
	30.0 at ≤ 50%F	0.47	0.55	0.46	0.50
	25.0 at ≤ 50%F	0.46	0.52	0.40	0.45

* Limits support operation with or without EOC-RPT-OOS and any combination of 1 MSRVOOS, up to 2 TIPOOS (or the equivalent number of TIP channels), and up to 50% of the LPRMs out-of-service. Base case supports single-loop operation.

† Limits are applicable for all the EOOS scenarios presented in Table 1.1 except those that include TBVOOS.

‡ Limits are applicable for all the EOOS scenarios presented in Table 1.1 including those with TBVOOS.

§ Nominal operation and FHOOS represents the feedwater temperatures shown in Figure 2.2 of Reference 20. Startup FHOOS 1 temperatures are presented in Item 6.6.1 of Reference 20. Startup FHOOS 2 temperatures represent an additional 5°F reduction from the values shown in Item 6.6.1 of Reference 20.

Table 8.10 LHGRFAC$_f$ Multipliers

Core Flow (% of rated)	ATRIUM 10XM LHGRFAC$_f$	ATRIUM-10 LHGRFAC$_f$
0.0	0.64	0.87
30.0	0.64	0.87
58.3	---	1.00
76.7	1.00	---
107.0	1.00	1.00

Table 8.11 MAPLHGR Limits

Average Planar Exposure (GWd/MTU)	ATRIUM 10XM MAPLHGR (kW/ft)	ATRIUM-10 MAPLHGR (kW/ft)
0.0	13.0	12.5
15.0	13.0	12.5
67.0	7.6	7.3

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TVA CONFIDENTIAL INFORMATION

TVA NPG

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To: G. C. Storey, Manager, Nuclear Fuel Engineering - BWRFE, COO, LP 4G-C

From: T. W. Eichenberg, Sr. Specialist, Reactor Engineering & Fuels - BWRFE, COO, LP 4G-C

Subject: Browns Ferry Unit 1 Cycle 12: FSAR Update Request Supporting COLR.

Ref: 1: NPG-SPP-03.15, Revision 1, **FSAR Management**, NPG Standard Programs and Processes, Tennessee Valley Authority, December 31, 2015.

Purpose

Reference 1, Section 3.1.1, identifies the FSAR division of responsibility (DOR). Nuclear Fuels is the responsible, lead organization (LO) for Appendix N of the FSAR; there are no formally associated support organizations (SO). This memo provides necessary documentation to reflect relevant aspects of COLR issuance. The following pages contain FSAR change request materials.

Completed: [signature] Sept 9, 2016
T. W. Eichenberg, Sr. Specialist — Date
Reactor Engineering and Fuels - BWRFE

Approved: [signature] 9/9/16
Greg C. Storey - Manager — Date
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cc:

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