framatome

Browns Ferry Unit 2 Cycle 22 Reload Analysis

ANP-3880
Revision 0

November 2020

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
ABSP	automated backup stability
AOT	abnormal operational transient
APLHGR	average planar linear heat generation rate
APRM	average power range monitor
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
BFE2-22	Browns Ferry Unit 2 Cycle 22
BOC	beginning-of-cycle
BPWS	banked position withdrawal sequence
BSP	backup stability protection
BWR	boiling water reactor
BWROG	Boiling Water Reactor Owners Group
CDA	confirmation density algorithm
CFR	Code of Federal Regulations
COLR	core operating limits report
CPR	critical power ratio
CRDA	control rod drop accident
CRWE	control rod withdrawal error
DSS-CD	detect and suppress solution – confirmation density
EFPD	effective full-power days
EFPH	effective full-power hours
EOC	end-of-cycle
EOCLB	end-of-cycle licensing basis
EOC-RPT	end-of-cycle recirculation pump trip
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
EPU	extended power uprate defined as 120 % OLTP
FFTR	final feedwater temperature reduction
FHOOS	feedwater heaters out-of-service
FSAR	final safety analysis report
FW	feedwater
FWCF	feedwater controller failure
GSF	generic shape function

Nomenclature
(Continued)

HPCI	high pressure coolant injection
ICF	increased core flow
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
LTA	lead test assembly
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
MELLLA+	maximum extended load line limit analysis plus
MSIV	main steam isolation valve
MSRV	main steam relief valve
MSRVOOS	main steam relief valve out-of-service
NCL	natural circulation line
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
RDF	rated drive flow
RHR	residual heat removal
RPT	recirculation pump trip
RTP	rated thermal power

Nomenclature
(Continued)

S_{AD}	amplitude discriminator setpoint
SLC	standby liquid control
SLMCPR	safety limit minimum critical power ratio
SLO	single-loop operation
STP	simulated thermal power
TBV	turbine bypass valve
TBVIS	turbine bypass valves in service
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 Framatome Inc. (Framatome) are presented in support of cycle operation with MELLLA+. The analyses reported in this document were performed using methodologies previously approved for generic application to boiling water reactors. The U. S. Nuclear Regulatory Commission (NRC) technical limitations and conditions associated with the application of the approved methodologies have been satisfied by these analyses.

The Browns Ferry Unit 2 Cycle 22 (BFE2-22) core consists of a total of 764 fuel assemblies including 308 fresh ATRIUM 10XM assemblies, 452 irradiated ATRIUM 10XM assemblies and 4 irradiated ATRIUM 11 lead test assemblies (LTA). Licensing analyses support the core design presented in Reference 1.

Reload licensing analyses were performed for potentially limiting events and analyses identified in Section 2.0. 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 analyses 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.

**Table 1.1 EOD and EOOS
Operating Conditions**

Extended Operating Domain (EOD) Conditions
Increased core flow (ICF)
Maximum extended load line limit analysis plus (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 up to 50 % of the LPRMs out-of-service.

† Note feedwater heaters out-of-service / FFTR and single-loop operation conditions are not allowed when operating in the MELLLA+ operating domain.

‡ 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 43.75 % of rated, and an active recirculation drive flow of 17.73 Mlb/hr.

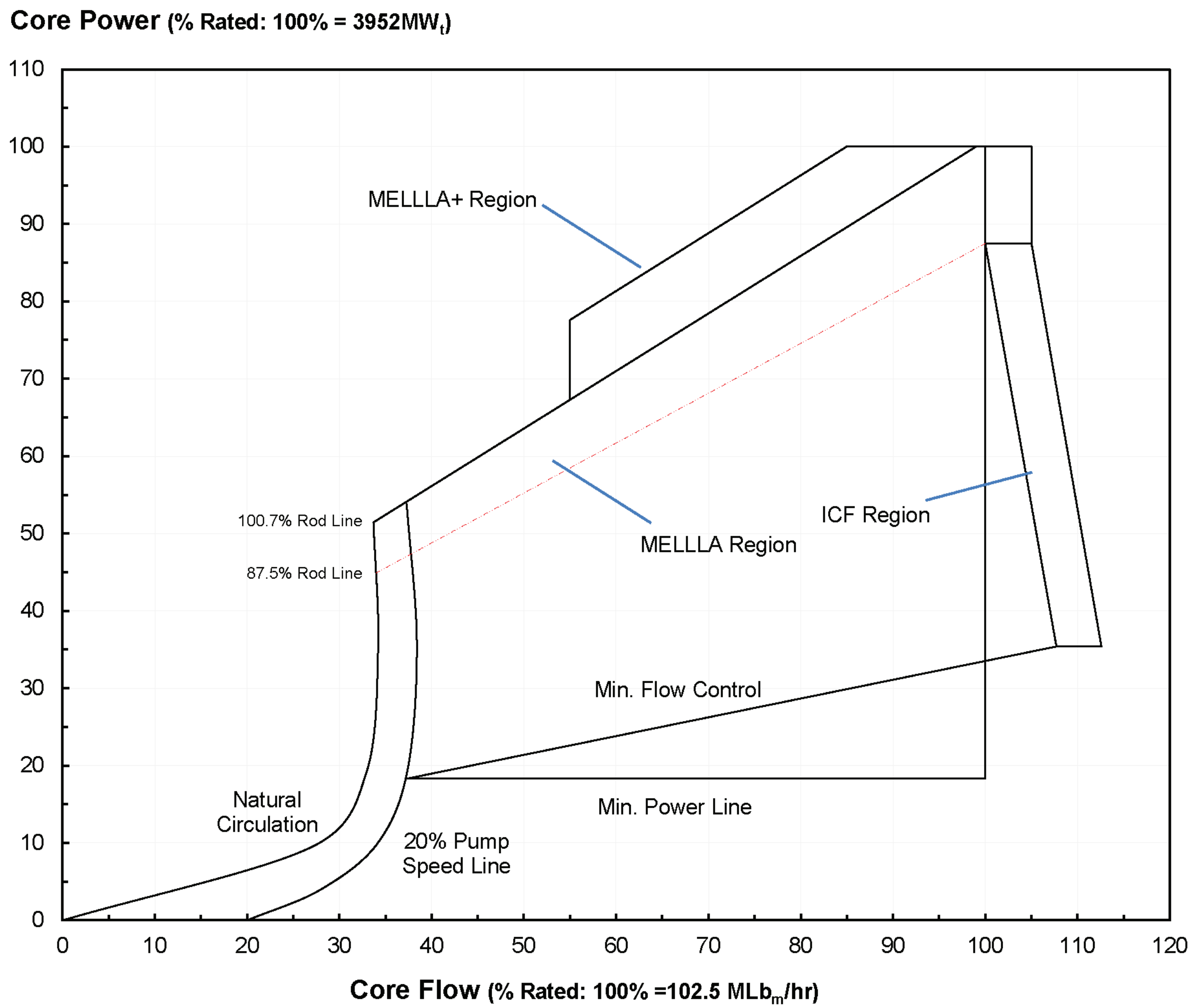

Figure 1.1 Power / Flow Map – EPU / MELLLA+

2.0 DISPOSITION OF EVENTS

A review of FSAR events was performed to support the first application of EPU (120 % OLTP) power with ATRIUM 10XM fuel (Reference 2). The goal of Reference 2 was to identify potentially limiting events and analyses requiring evaluation either on a cycle-specific basis or generically. When changes to plant configurations are implemented, a review of the Reference 2 conclusions is warranted.

Parameter differences between the initial Browns Ferry ATRIUM 10XM licensing analyses and the BFE2-22 reload were reviewed to determine if the conclusions remain applicable. The affected analyses were included in the Reference 3 calculation plan and addressed as part of the reload analyses.

3.0 MECHANICAL DESIGN ANALYSIS

NRC approved exposure limits for ATRIUM 10XM are presented in References 4, 5, 6, 7, and 8. ATRIUM 11 LTA fuel exposure limits are presented in References 9 and 10. 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 thicknesses are presented in Tables 3-2 and 3-3 of Reference 8 for ATRIUM 10XM fuel and Table A-3 of Reference 9 for ATRIUM 11 LTA. The calculated oxide thickness complies with the limit provided in Section 3.2.7 of Reference 11.

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 12. Analysis results demonstrate the thermal-hydraulic design and compatibility criteria are satisfied for the equilibrium core consisting of ATRIUM 10XM and ATRIUM 11 LTA.

4.2 *Safety Limit MCPR Analysis*

The safety limit MCPR (SLMCPR) is defined as the minimum value of the critical power ratio (CPR) 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 13. The analysis was performed with a power distribution conservatively representing expected reactor operation throughout the cycle.

The SLMCPR analysis used the ACE/ATRIUM 10XM critical power correlation (References 14 and 15) for the ATRIUM 10XM and the SPCB critical power correlation (Reference 16) for the ATRIUM 11 LTA.

In the Framatome methodology, the effects of channel bow on the critical power performance are accounted for in the SLMCPR analysis. Reference 13 discusses the application of a realistic channel bow model. For BFE2-22, the channel bow model uncertainty has been augmented for those channels experiencing 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 2,500 EFPH LPRM calibration interval.

Analysis results support a two-loop operation (TLO) SLMCPR of 1.06 and a 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*

4.3.1 Stability DSS-CD Solution

Browns Ferry has implemented the stability DSS-CD solution using the Oscillation Power Range Monitor (OPRM) as described in Reference 17. Plant-specific analyses for the DSS-CD Solution are provided in Reference 18. The Detect and Suppress function of the DSS-CD solution based on the OPRM system relies on the Confirmation Density Algorithm (CDA) which constitutes the licensing basis. The Backup Stability Protection (BSP) solution may be used by the plant in the event the OPRM system is declared inoperable.

The CDA enabled through the OPRM system and the BSP solution described in Reference 18 are the stability licensing basis for Browns Ferry operation in the MELLLA+ region. The applicability of the DSS-CD solution and the Amplitude Discriminator Setpoint (S_{AD}) of the CDA were confirmed by TVA for the Unit 2 Cycle 22 core. TVA utilized the extended applicability checklists provided in Reference 17 to document the DSS-CD solution applicability to Unit 2 Cycle 22. The S_{AD} value provided in Reference 18 was confirmed by TVA to apply to Unit 2 Cycle 22 using the process provided in Reference 18.

4.3.2 DSS-CD Backup Stability Protection

Reference 17 describes two BSP options based on selected elements from three distinct constituents: BSP Manual Regions, BSP Boundary, and Automated BSP (ABSP) setpoints.

The Manual BSP region boundaries were calculated for Browns Ferry Unit 2 Cycle 22 using STAIF (Reference 19) for nominal and reduced feedwater temperature operation (both FFTR and FHOOS). The endpoints of the regions are defined in Table 4.3 and Table 4.4 for nominal and reduced feedwater temperature, respectively. The Manual BSP region boundary endpoints are connected using the Generic Shape Function (GSF) and are provided with Table 4.5 and Table 4.6 for nominal and reduced feedwater temperature, respectively. The BSP Boundary for nominal and reduced feedwater temperature is defined by the MELLLA boundary line, per Reference 20. The ABSP Average Power Range Monitor (APRM) Simulated Thermal Power (STP) setpoints associated with the ABSP Scram Region are listed in Table 4.7. These ABSP setpoints are applicable to nominal and reduced feedwater temperature operation.

4.4 *Voiding in the Channel Bypass Region*

To demonstrate compliance with the NRC's 5 % maximum bypass voiding around the LPRM requirement (see Section 5.1.1.5.1 of the Reference 21 Safety Evaluation), the bypass void level has been evaluated throughout the cycle. The maximum bypass void value at the LPRM 'D' level and at the axial elevation equivalent to the top of the TIP tube have been confirmed to remain below this limit for the Cycle 22 design.

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

Minimum Supported SLMCPR	Percentage of Rods in Boiling Transition
TLO – 1.06	0.0963
SLO – 1.08	0.0905

Table 4.3 DSS-CD BSP Endpoints for Nominal Feedwater Temperature

Endpoint	Power (%)	Flow (%)	Definition
A1	75.9	52.7	Scram Region (Region I) Boundary Intercept on MELLLA+ Line
B1	35.5	29.0	Scram Region (Region I) Boundary Intercept on NCL
A2	66.1	52.0	Controlled Entry Region (Region II) Boundary Intercept on MELLLA Line
B2	25.5	29.0	Controlled Entry Region (Region II) Boundary Intercept on NCL

Table 4.4 DSS-CD BSP Endpoints for Reduced Feedwater Temperature

Endpoint	Power (%)	Flow (%)	Definition
A1	64.9	50.5	Scram Region (Region I) Boundary Intercept on MELLLA Line
B1	29.4	29.0	Scram Region (Region I) Boundary Intercept on NCL
A2	68.3	54.9	Controlled Entry Region (Region II) Boundary Intercept on MELLLA Line
B2	24.5	29.0	Controlled Entry Region (Region II) Boundary Intercept on NCL

Table 4.5 Nominal Feedwater Temperature Boundary Points

Scram Region		Exit Region	
Flow (% rated)	Power (% rated)	Flow (% rated)	Power (% rated)
52.70	75.90	52.00	66.10
51.52	71.76	50.85	61.62
50.33	67.98	49.70	57.57
49.15	64.52	48.55	53.92
47.96	61.35	47.40	50.63
46.78	58.45	46.25	47.64
45.59	55.79	45.10	44.94
44.41	53.36	43.95	42.50
43.22	51.13	42.80	40.28
42.04	49.08	41.65	38.27
40.85	47.20	40.50	36.45
39.67	45.49	39.35	34.79
38.48	43.92	38.20	33.29
37.30	42.48	37.05	31.94
36.11	41.17	35.90	30.70
34.93	39.98	34.75	29.59
33.74	38.89	33.60	28.59
32.56	37.90	32.45	27.68
31.37	37.02	31.30	26.87
30.19	36.22	30.15	26.15
29.00	35.50	29.00	25.50

Table 4.6 Reduced Feedwater Temperature Boundary Points

Scram Region		Exit Region	
Flow (% rated)	Power (% rated)	Flow (% rated)	Power (% rated)
50.50	64.90	54.90	68.30
49.43	61.22	53.61	63.33
48.35	57.86	52.31	58.87
47.28	54.79	51.02	54.86
46.20	51.99	49.72	51.26
45.13	49.43	48.43	48.01
44.05	47.09	47.13	45.09
42.98	44.95	45.84	42.46
41.90	43.00	44.54	40.08
40.83	41.20	43.25	37.93
39.75	39.56	41.95	35.99
38.68	38.07	40.66	34.23
37.60	36.70	39.36	32.65
36.53	35.45	38.07	31.21
35.45	34.31	36.77	29.92
34.38	33.27	35.48	28.76
33.30	32.33	34.18	27.71
32.23	31.48	32.89	26.77
31.15	30.71	31.59	25.92
30.08	30.02	30.30	25.17
29.00	29.40	29.00	24.50

Table 4.7 ABSP Setpoints for the Scram Region

Parameter	Symbol	Setting Value (Unit)	Comments
Slope for Trip	m_{TRIP}	2.00 (% RTP / % RDF)	Slope of ABSP APRM flow-biased trip linear segment.
Constant Power Line for Trip	$P_{BSP\text{-}TRIP}$	35.0 (% RTP)	ABSP APRM flow-biased trip setpoint power intercept. Constant Power Line for Trip from zero Drive Flow to Flow Breakpoint value.
Constant Flow Line for Trip	$W_{BSP\text{-}TRIP}$	≥ 49 (% RDF)	ABSP APRM flow-biased trip setpoint drive flow intercept. Constant Flow Line for Trip. (see Note 1)
Flow Breakpoint	$W_{BSP\text{-}BREAK}$	30.0 (% RDF)	Flow Breakpoint value

Note 1: $W_{BSP\text{-}TRIP}$ can be set to 49.0 % RDF or any higher value up to the intersection of the ABSP sloped line with the APRM flow-biased STP scram line.

5.0 ANTICIPATED OPERATIONAL OCCURRENCES

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

CASMO-4/MICROBURN-B2 (Reference 22), COTRANSA2 (Reference 23), XCOBRA (Reference 24), and XCOBRA-T (Reference 25) are the major codes used in the thermal limits analyses as described in the Framatome THERMEX methodology report (Reference 24) and neutronics methodology report (Reference 22). COTRANSA2 is a system transient simulation code which includes an axial one-dimensional neutronics model capturing the effects of axial power shifts associated with the system transients. XCOBRA is used in steady-state analyses. XCOBRA-T is a transient thermal-hydraulics code used in the analysis of thermal margins for the limiting fuel assembly. The ACE/ATRIUM 10XM critical power correlation (References 14 and 15) is used to evaluate the thermal margin for the ATRIUM 10XM fuel. Fuel pellet-to-cladding gap conductance values are based on RODEX2 (Reference 26) calculations for the BFE2-22 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 $MCPR_p$ limits protecting operation throughout the power / flow domain depicted in Figure 1.1. For the Browns Ferry Unit 2 Cycle 22 core design, the ATRIUM 11 LTA are confined to low power near peripheral locations and will not challenge thermal limits. As a result, explicit cycle-specific transient results for the ATRIUM 11 LTA are not provided; however, reasonable thermal limits for the ATRIUM 11 LTA are provided.

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 26 % 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 23 % of rated, which is the lowest power analyzed for this report, consistent with Reference 27.

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. Analyses were performed at cycle exposures prior

to NEOC to ensure the operating limits provide the necessary protection. The end-of-cycle licensing basis (EOCLB) analysis was performed at EOFP + 15 EFPD. 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) is inoperable. The basis supports operation with 1 MSRV out-of-service.

Reductions in feedwater temperature of less than 15 ºF from the nominal feedwater temperature and variations of ±10 psi in dome pressure are considered base case operation not an EOOS condition. Although the base case operating condition assumes a maximum reduction of 15 ºF from the nominal feedwater temperature, the Browns Ferry Operating License does not allow operation at 100 % power in the MELLLA+ domain with final feedwater temperature less than 384.5 ºF. 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 70 ºF (55 ºF + 15 ºF bias) at rated power. Analyses were performed to support combined FFTR / Coastdown operation to the core average exposure provided in Table 5.1. The analyses were performed with the limiting feedwater and dome pressure conditions in the allowable ranges. Operation with FFTR is not allowed in the MELLLA+ operating domain.

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 analytically adjusted timing for 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 compared to the surveillance testing timing. 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.

The Technical Specifications (Reference 27) 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 scram speeds were made to the analysis inputs to appropriately

account for these effects on scram reactivity. For cases below 26 % power, the results are relatively insensitive to scram reactivity and only TSSS analyses are performed. At 26 % 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 TCV. The TCV closure creates a pressure compression wave traveling through the steam lines into the vessel causing 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 TCV 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 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 TCV 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 Figure 5.1 – Figure 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 pressure compression wave traveling through the steam lines into the vessel causing a rapid pressurization. The increase in pressure causes 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 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 the TSV (0.150 second compared to 0.100 second), 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 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 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 TSV to close in order to prevent damage to the turbine from excessive liquid inventory in the steam line. Valve closure creates a pressure compression wave traveling back to the core causing void collapse and a subsequent rapid power excursion. The closure of the TSV also initiates a reactor scram and an RPT. In addition to the TSV closure, the TCV 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 such 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 (TBV) are assumed operable and provide some pressure relief. The core power excursion is mitigated in part by pressure relief; however, 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 at power levels equal to and greater than 65 % assume a maximum feedwater runout of 22.79 Mlbm/hr. For power levels equal to above P_{bypass} (26 % power) up to 65 %, analyses assumed a maximum feedwater runout of 19.82 Mlbm/hr. For power levels below P_{bypass}, a maximum feedwater runout of 16.68 Mlbm/hr was assumed. A discussion of this input is provided in Comment 25 of Reference 28.

Table 5.4 presents the base case limiting FWCF transient analysis results used to generate the NEOC and EOCLB operating limits. Figure 5.4 - Figure 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 ºF decrease in the feedwater temperature. The result is an increase in core inlet subcooling which reduces voids thereby increasing core power and shifting the axial power distribution towards 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 TCV or TBV, so no pressurization occurs. A cycle-specific analysis was performed in accordance with the Reference 29 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 which lowers 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 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. 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.

5.2 *Slow Flow Runup Analysis*

Flow-dependent MCPR limits 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 CPR 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 SLMCPR 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 SLMCPR 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 $MCPR_f$ limits and $LHGRFAC_f$ 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 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.

Table 5.10 presents the limiting $LHGRFAC_p$ transient analysis results for each EOOS scenario used to generate the operating limits for all scram insertion times.

5.3.1 <u>TBVOOS</u>

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 TBV 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 70 ºF (55 ºF + 15 ºF bias) at rated power and steam flow. The effect of reduced feedwater temperature is an increase in core inlet subcooling changing the 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 TCV 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 as

provided in Item 6.6.1 of Reference 28. 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 28. If this requirement is met, reactor startup is restricted to the 85 % rod line or less.

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.

Analysis assumptions have been constructed to seek a balance between operating flexibility and margin to thermal limits. Maximum core power is restricted to 43.75 % of rated and core flow is restricted to 50 % of rated; active recirculation drive flow is assumed $\leq$ 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 Framatome 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 34,233.1 MWd/MTU is given in Table 5.11. 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 5.11 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 5.11 was calculated using the MICROBURN-B2 code. Compliance analyses must also be performed using MICROBURN-B2 or POWERPLEX-XD. Note 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.

Table 5.1 Exposure Basis for Transient Analysis

Core Average Exposure (MWd/MTU)	Comments
16,320.3	Beginning of cycle
31,055.6	Break point for exposure-dependent $MCPR_p$ limits (NEOC)
34,233.1	Design basis rod patterns to EOFP + 15 EFPD (EOCLB)
35,926.7	Maximum licensing core exposure - including FFTR /Coastdown
34,079.5	Cycle 21 EOC (short window)
34,651.8	Cycle 21 EOC (nominal window)
35,004.9	Cycle 21 EOC (long window)

Table 5.2 Scram Speed Insertion Times

Surveillance Timing			Control Rod Position (notch)	Analytically Adjusted Timing		
TSSS (seconds)	NSS (seconds)	OSS (seconds)		TSSS (seconds)	NSS (seconds)	OSS (seconds)
- - -	0.000	0.000	48 (full out)	0.000	0.000	0.000
- - -	0.200	0.200	48	0.200	0.200	0.200
0.45	0.420	0.380	46	0.460	0.421	0.392
1.08	0.980	0.875	36	1.090	0.991	0.887
1.84	1.600	1.465	26	1.860	1.620	1.487
3.36	2.900	2.900	6	3.500	3.040	3.040
- - -	- - -	- - -	0 (full in)	4.000	3.500	3.500

Table 5.3 Base Case LRNB Transient ΔCPR Results*

Power (% rated)	NEOC	EOCLB
TSSS Insertion Times		
50.0	0.77	0.77
40.0	0.87	0.87
NSS Insertion Times		
50.0	0.76	0.76
40.0	0.86	0.86
OSS Insertion Times		
50.0	0.76	0.76
40.0	0.86	0.86

* Based on previous EPU analyses and as discussed in Table A.2 of Reference 3, the LRNB event at high core power and 26 % power is bound by the FWCF event.

Table 5.4 Base Case FWCF Transient ΔCPR Results

Power (% rated)	NEOC	EOCLB
TSSS Insertion Times		
100.0	0.39	0.41
90.0	0.44	0.44
77.6	0.51	0.51
65.0	0.57	0.57
60.0	0.57	0.57
55.0	0.60	0.60
50.0	0.65	0.65
40.0	0.78	0.78
26.0	1.24	1.24
26.0 at > 50 % F below P_{bypass}	1.41	1.41
26.0 at ≤ 50 % F below P_{bypass}	1.32	1.32
23.0 at > 50 % F below P_{bypass}	1.56	1.56
23.0 at ≤ 50 % F below P_{bypass}	1.46	1.46
NSS Insertion Times		
100.0	0.36	0.38
90.0	0.41	0.42
77.6	0.49	0.49
65.0	0.55	0.56
60.0	0.55	0.56
55.0	0.59	0.59
50.0	0.63	0.64
40.0	0.77	0.77
26.0	1.22	1.22

Table 5.4 Base Case FWCF Transient ΔCPR Results
(Continued)

Power (% rated)	NEOC	EOCLB
OSS Insertion Times		
100.0	0.32	0.36
90.0	0.38	0.39
77.6	0.46	0.47
65.0	0.52	0.54
60.0	0.53	0.54
55.0	0.57	0.58
50.0	0.61	0.62
40.0	0.75	0.75
26.0	1.20	1.20

Table 5.5 Loss of Feedwater Heating Transient Analysis Results

Power (% rated)	ΔCPR
100	0.12
90	0.13
80	0.14
70	0.15
60	0.16
50	0.18
40	0.21
30	0.26
23	0.31

Table 5.6 Control Rod Withdrawal Error ΔCPR Results

Analytical RBM Setpoint (without filter) (%)	ΔCPR	CRWE MCPR*
107	0.22	1.28
111	0.28	1.34
114	0.31	1.37
117	0.33	1.39

* For rated power and a 1.06 SLMCPR.

Table 5.7 RBM Operability Requirements

Thermal Power (% rated)	Applicable MCPR
≥27 % and < 90 %	1.72 TLO 1.76 SLO
≥ 90 %	1.41 TLO

Table 5.8 Flow-Dependent MCPR Results

Core Flow (% rated)	MCPR
30	1.26
40	1.22
50	1.23
60	1.24
70	1.23
80	1.18
90	1.15
100	1.12
107	1.06

Table 5.9 RCPOOS Pump Seizure Results

State point Power / Flow (% rated)	ΔCPR
43.75 / 50	0.95

Table 5.10 LHGRFACp Transient Results*

Power (% rated)	Base Case	FHOOS	PLUOOS	PLUOOS and FHOOS	TBVOOS	TBVOOS and FHOOS
100.0	1.00	1.00	1.00	1.00	1.00	1.00
90.0	1.00	1.00	1.00	1.00	1.00	1.00
77.6	1.00	1.00	1.00	1.00	1.00	1.00
65.0	1.00	1.00	1.00	1.00	1.00	0.99
60.0	0.98	0.98	0.98	0.98	0.96	0.96
55.0	0.97	0.97	0.97	0.97	0.94	0.95
50.0	0.95	0.94	0.95	0.94	0.92	0.92
40.0	0.90	0.89	0.90	0.89	0.83	0.83
26.0	0.70	0.67	0.70	0.67	0.66	0.66
26.0 at > 50 % F below P_{bypass}	0.51	0.51	0.51	0.51	0.45	0.43
23.0 at > 50 % F below P_{bypass}	0.47	0.47	0.47	0.47	0.42	0.40
26.0 at ≤ 50 % F below P_{bypass}	0.55	0.55	0.55	0.55	0.55	0.54
23.0 at ≤ 50 % F below P_{bypass}	0.53	0.53	0.53	0.53	0.48	0.48

Power (% rated)	SFHOOS1 TBVIS	SFHOOS1 TBVOOS	SFHOOS2 TBVIS	SFHOOS2 TBVOOS
50.0	0.85	0.85	0.85	0.85
40.0	0.74	0.74	0.74	0.74
26.0	0.58	0.57	0.58	0.57
26.0 at > 50 % F below P_{bypass}	0.45	0.40	0.44	0.39
23.0 at > 50 % F below P_{bypass}	0.42	0.36	0.42	0.36
26.0 at ≤ 50 % F below P_{bypass}	0.49	0.46	0.50	0.46
23.0 at ≤ 50 % F below P_{bypass}	0.48	0.44	0.47	0.44

* Results support operation with or without EOC-RPT-OOS and are presented for all cycle exposures and scram insertion times.

Table 5.11 Licensing Basis Core Average Axial Power Profile

State Conditions for Power Shape Evaluation	
Power, MWt	3,952.0
Core pressure, psia	1,050.0
Inlet subcooling, Btu/lbm	25.6
Flow, Mlb/hr	107.6
Control state	ARO
Core average exposure (EOCLB), MWd/MTU	34,233.1

Licensing Axial Power Profile
(Normalized)

Node	Power
Top 25	0.264
24	0.679
23	0.865
22	0.994
21	1.091
20	1.162
19	1.201
18	1.239
17	1.256
16	1.259
15	1.275
14	1.257
13	1.403
12	1.411
11	1.380
10	1.339
9	1.271
8	1.153
7	1.022
6	0.898
5	0.766
4	0.652
3	0.572
2	0.458
Bottom 1	0.135

Sum of Bottom 7 Nodes = 4.503

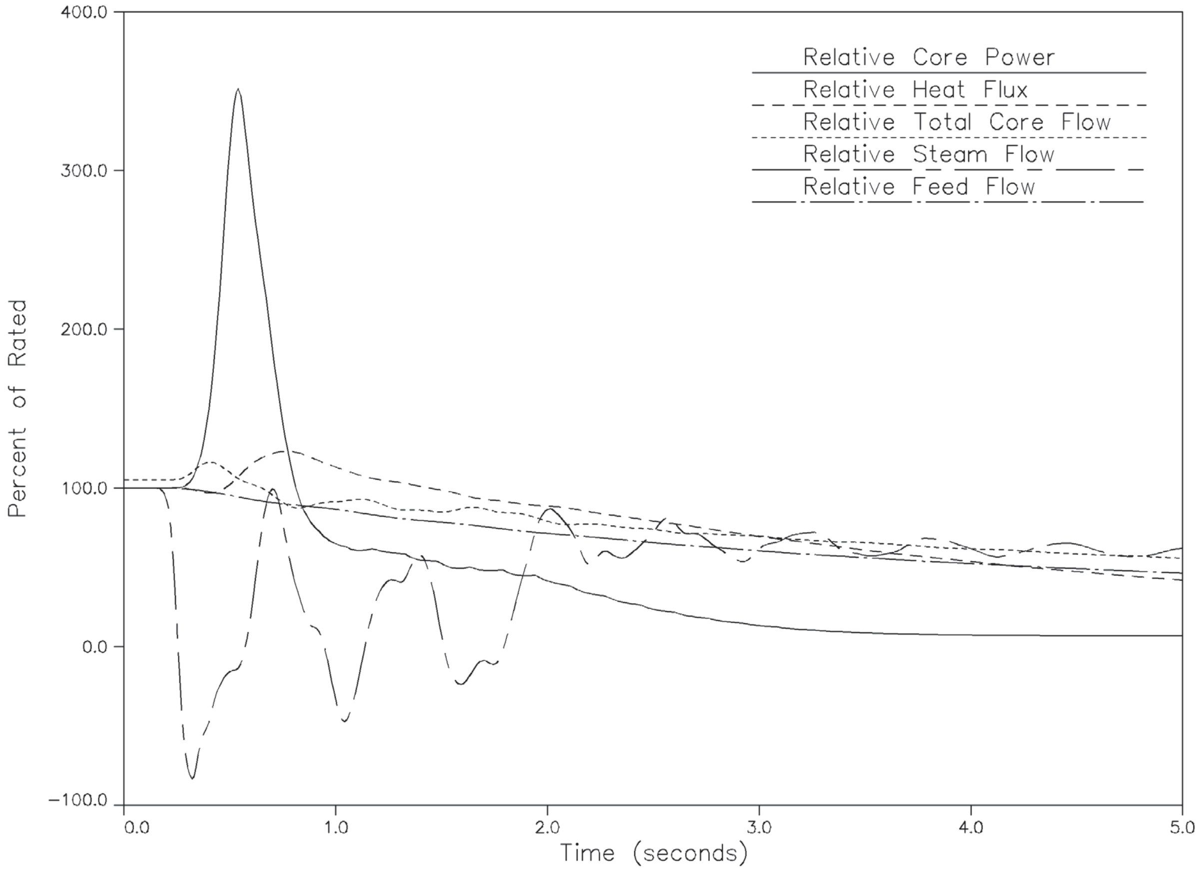

Figure 5.1 EOCLB LRNB at 100P / 105F – TSSS
Key Parameters

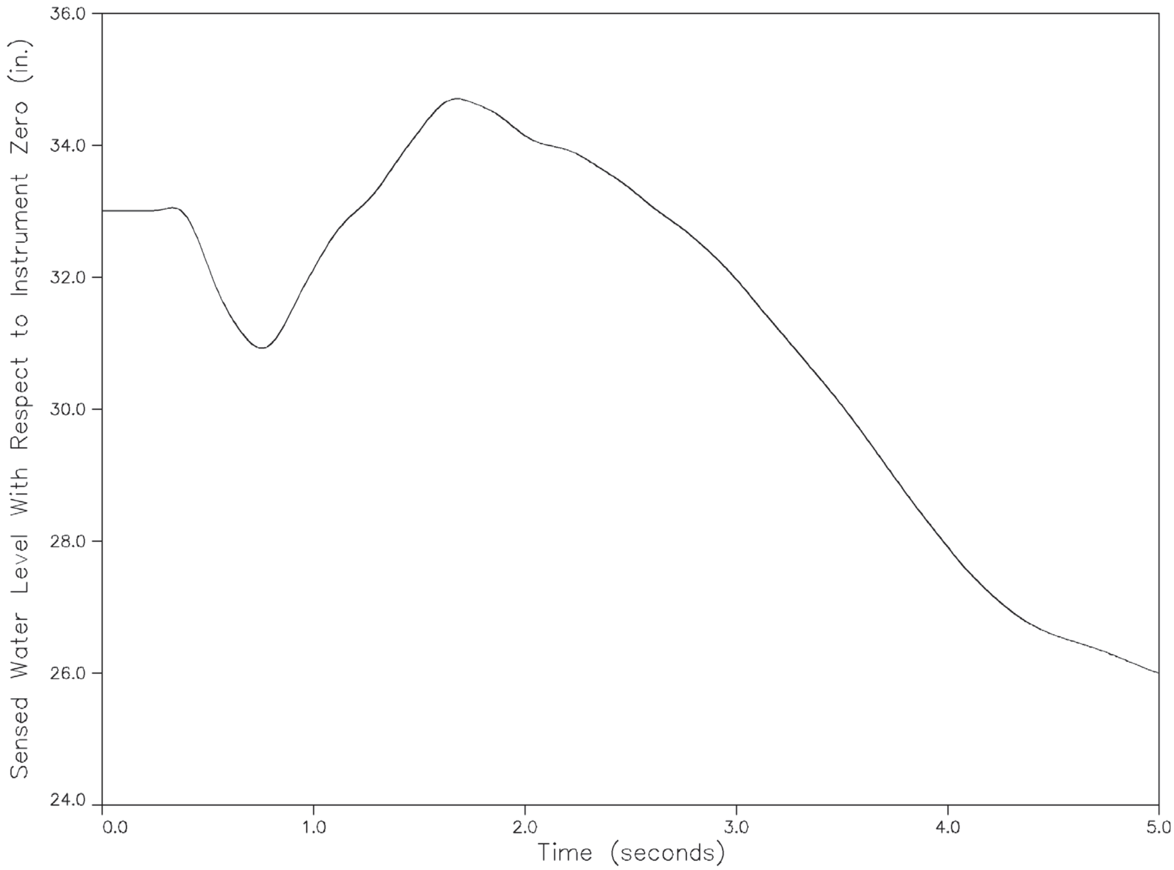

Figure 5.2 EOCLB LRNB at 100P / 105F – TSSS Sensed Water Level

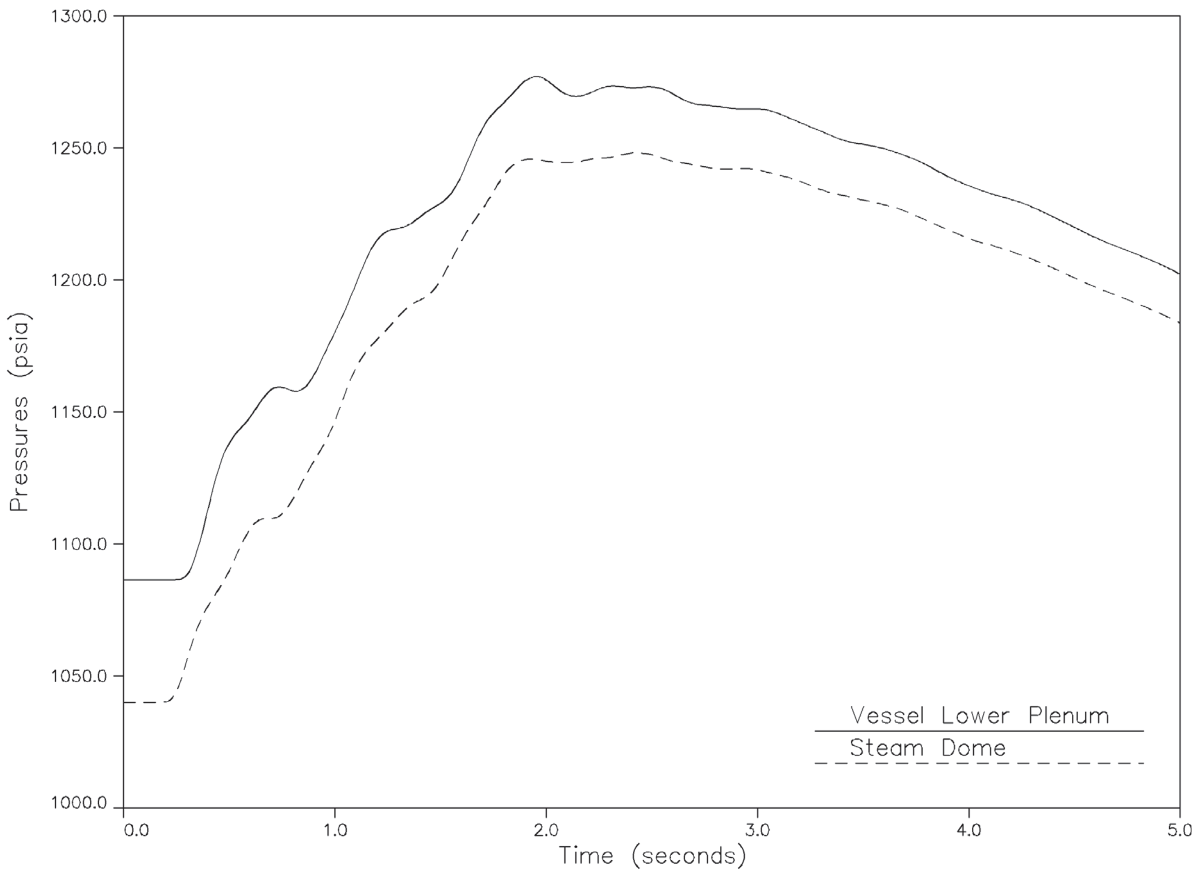

Figure 5.3 EOCLB LRNB at 100P / 105F – TSSS
Vessel Pressures

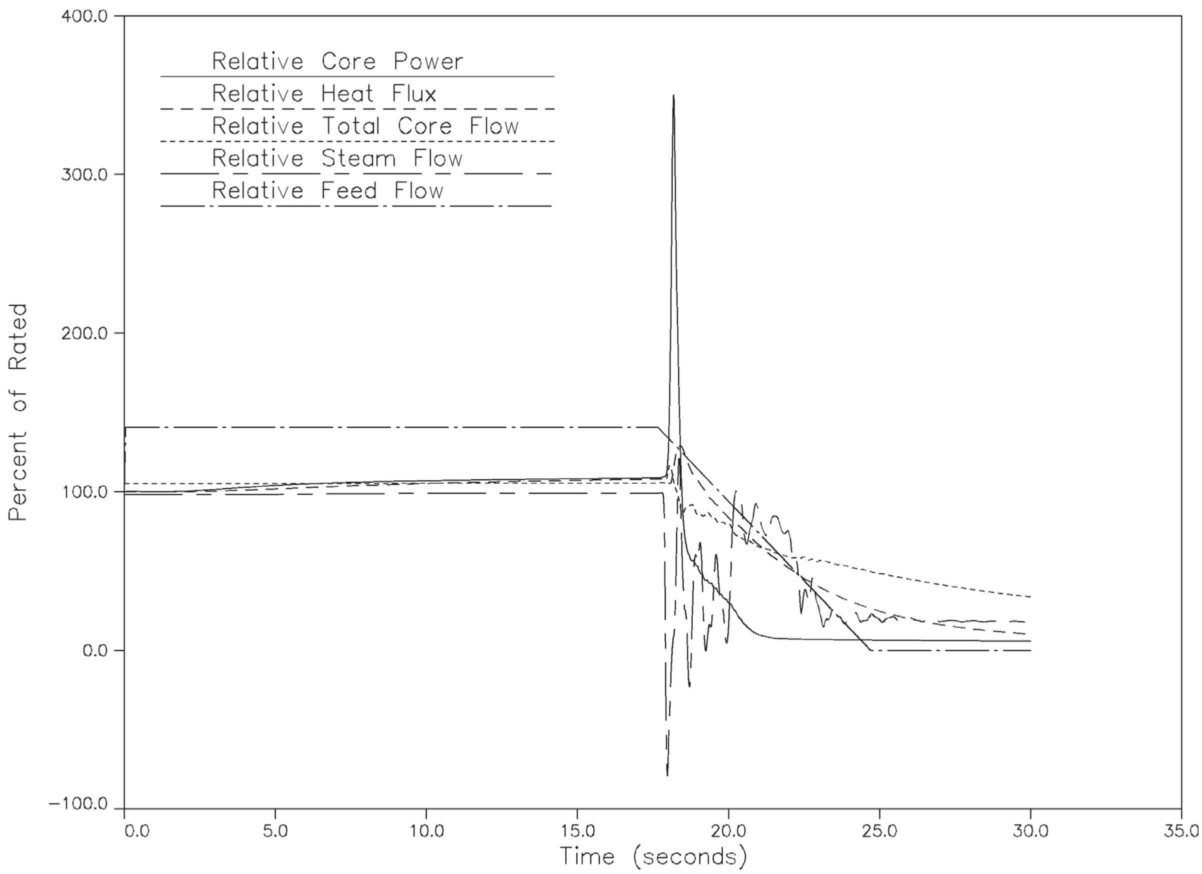

Figure 5.4 EOCLB FWCF at 100P / 105F – TSSS
Key Parameters

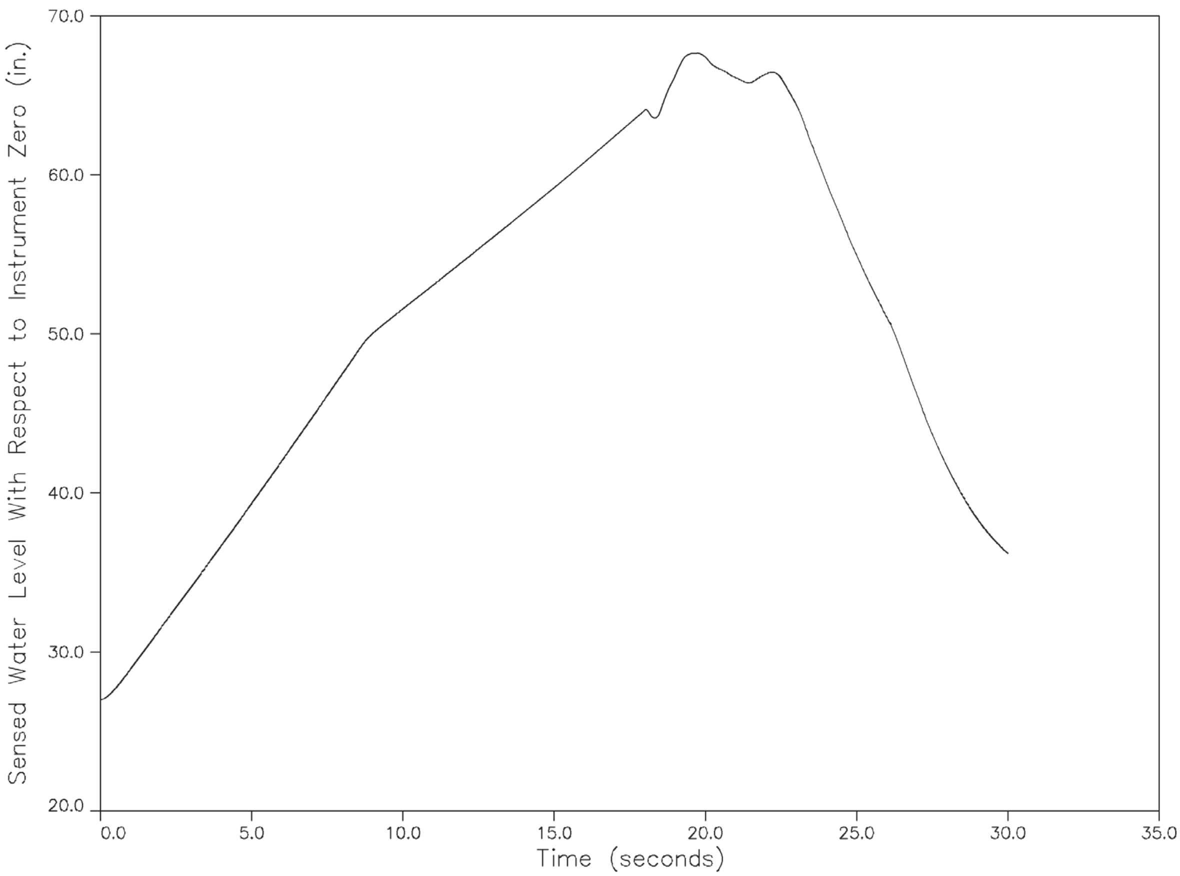

Figure 5.5 EOCLB FWCF at 100P / 105F – TSSS
Sensed Water Level

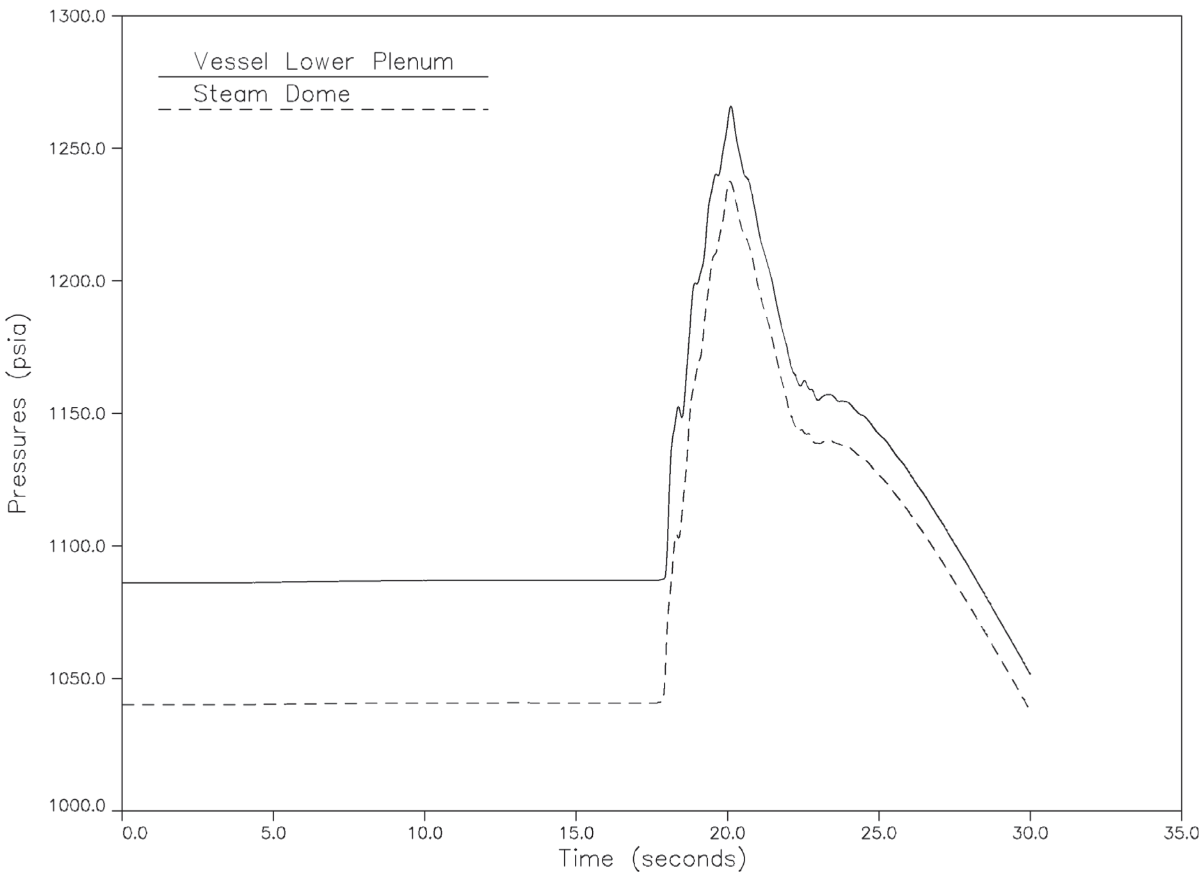

Figure 5.6 EOCLB FWCF at 100P / 105F – TSSS
Vessel Pressures

6.0 POSTULATED ACCIDENTS

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

The results of the ATRIUM 10XM LOCA analysis are presented in References 30 and 31 as supplemented by Reference 32. The ATRIUM 10XM PCT is 2,052 ºF. The peak local metal water reaction is 2.06 % 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 is bounded by the limiting neutronic design used in Reference 31. 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 11 LTA are calculated and supplemented by Reference 32. The ATRIUM 11 PCT IS 1,905 ºF. The peak local metal water reaction is 1.29 %.

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. The CRDA evaluation was performed for both A and B sequence startups consistent with the withdrawal sequences specified by TVA. The approved Framatome 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 11.

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 on the following page.

Maximum dropped control rod worth, mk	8.14
Core average Doppler coefficient, Δk/k/ºF	-10.5×10^{-6}
Effective delayed neutron fraction	0.0052
Four-bundle local peaking factor	1.525
Maximum deposited fuel rod enthalpy, cal/g	157.1
Maximum number of assemblies exceeding 170 cal/g	0
Number of rods failed	0

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 and ATRIUM 11 source terms have 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 10XM and ATRIUM 11 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 criterion is 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

Framatome 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**

Framatome has performed a bounding fuel assembly misorientation analysis. The analysis was performed assuming the limiting assembly was loaded in the worst orientation (rotated 180 º), 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 the 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 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 Framatome plant simulator code COTRANSA2 (Reference 23) for 102 % power and both 85 % 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 voids which in turn causes a rapid increase in power. The TBV 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 or motion) 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 one of the lowest setpoint MSRV 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, 1,070 psia (1,055 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 Figure 7.1 – Figure 7.4. The maximum pressure of 1,343 psig occurs in the lower plenum. The maximum dome pressure for the same event is 1,308 psig. The results demonstrate the maximum vessel pressure limit of 1,375 psig and dome pressure limit of 1,325 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 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 (1,500 psig). Overpressurization analyses were performed at 100 % power at both 85 % and 105 % flow over the cycle exposure range for both the MSIV closure event and the pressure regulator failure open (PRFO) event. The PRFO event assumes a step decrease in pressure demand such that the pressure control system opens the TCV and TBV. Steam flow demand is assumed to increase to 125 % demand (equivalent to 131.3 % of rated steam flow) allowing a maximum TCV flow of 105 % and a maximum bypass system flow of 21.3 %. The system pressure decreases until the low pressure setpoint is reached resulting in the closure of the MSIV. 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 one of the lowest setpoint MSRV was inoperable.
- All scram functions were disabled.
- The initial dome pressure was set to the nominal pressure of 1,050 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 Figure 7.5 – Figure 7.8. The maximum lower plenum pressure is 1,493 psig and the maximum dome pressure is 1,474 psig. The results demonstrate the ATWS maximum vessel pressure limit of 1,500 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.

An evaluation of ATRIUM 10XM fuel at EPU conditions was presented in Section 7.2.2 of Reference 37. The ATRIUM 11 LTA were addressed in Section 2.9.2 of Reference 38. These evaluations concluded the introduction of the respective fuel design does not significantly impact the long term ATWS response (suppression pool temperature and containment pressure) and the current analysis remains applicable. This conclusion is applicable for the BFE2-22 core design.

7.3 *Standby Liquid Control System*

In the event 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 2 SLC system is required to be able to inject 720 ppm natural boron equivalent at 70 ºF into the reactor coolant. Framatome 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 ºF with a boron concentration equivalent to 720 ppm at 68 ºF*. The temperature of 366 ºF 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 2.51 % Δk/k based on the short Cycle 21 EOC.

7.4 *Fuel Criticality*

The spent fuel pool criticality analysis for ATRIUM 10XM fuel is presented in Reference 39. The ATRIUM 11 LTA were determined to be less reactive than the ATRIUM 10XM reference bounding lattices evaluated in Reference 39. The ATRIUM 10XM and ATRIUM 11 fuel assemblies identified for the cycle meet the spent fuel storage requirements. ATRIUM 10XM and ATRIUM 11 fuel assemblies will not be stored in the new fuel storage vault.

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

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)	278	128	1,343	1,308
TSV closure without bypass (102P / 105F)	451	138	1,338	1,303
TCV closure without bypass (102P / 105F)	451	137	1,338	1,303
Pressure Limit	---	---	1,375	1,325

* 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 / 85F)	289	134	1,488	1,470
PRFO (100P / 85F)	256	140	1,493	1,474
Pressure Limit	---	---	1,500	1,500

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

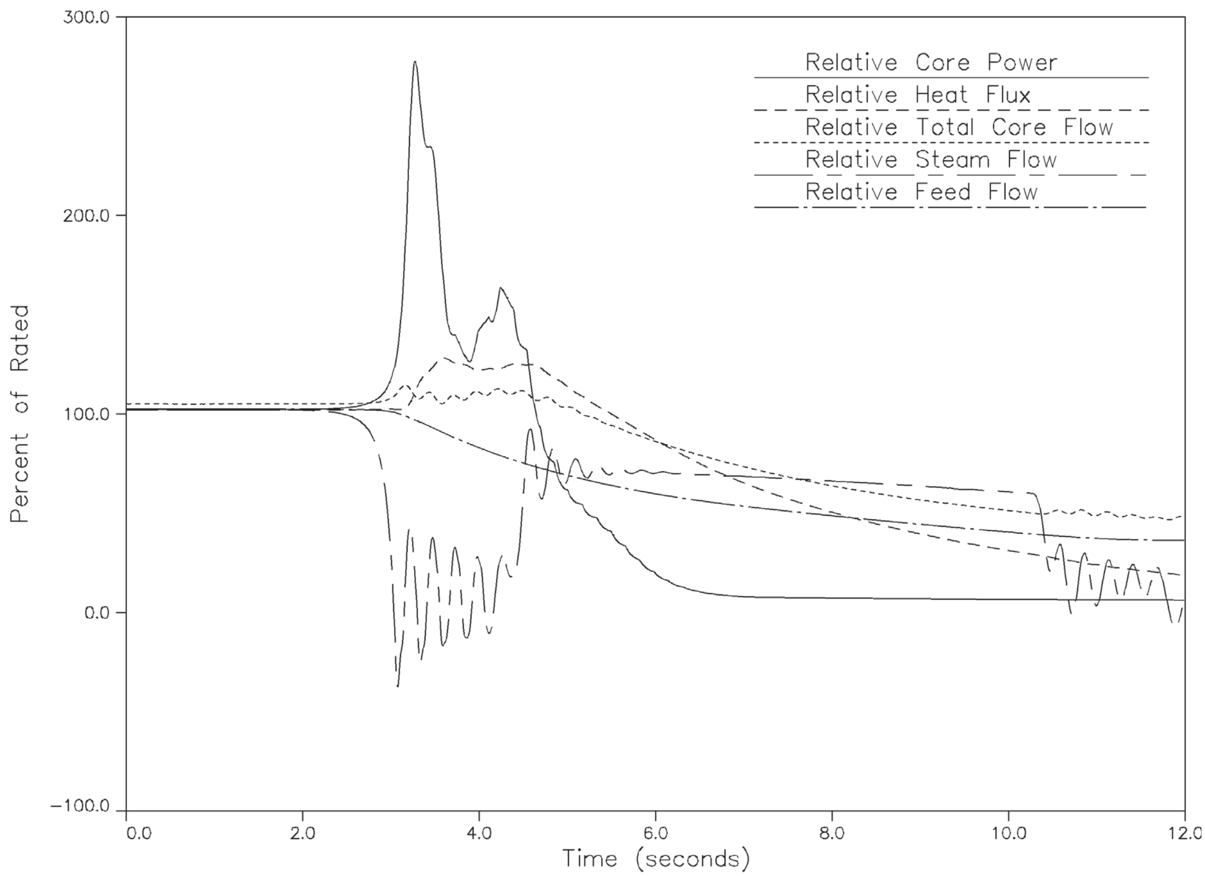

Figure 7.1 MSIV Closure Overpressurization Event at 102P / 105F – Key Parameters

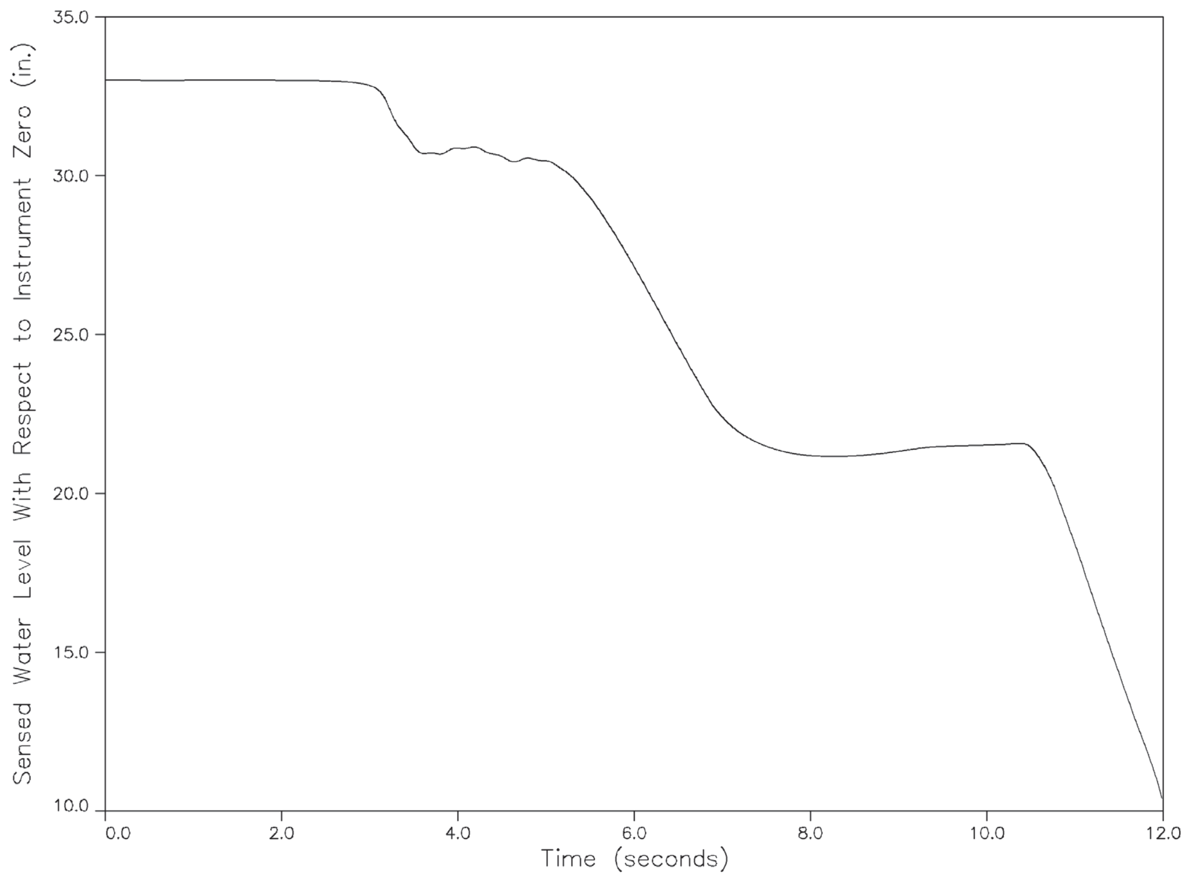

Figure 7.2 MSIV Closure Overpressurization Event at 102P / 105F – Sensed Water Level

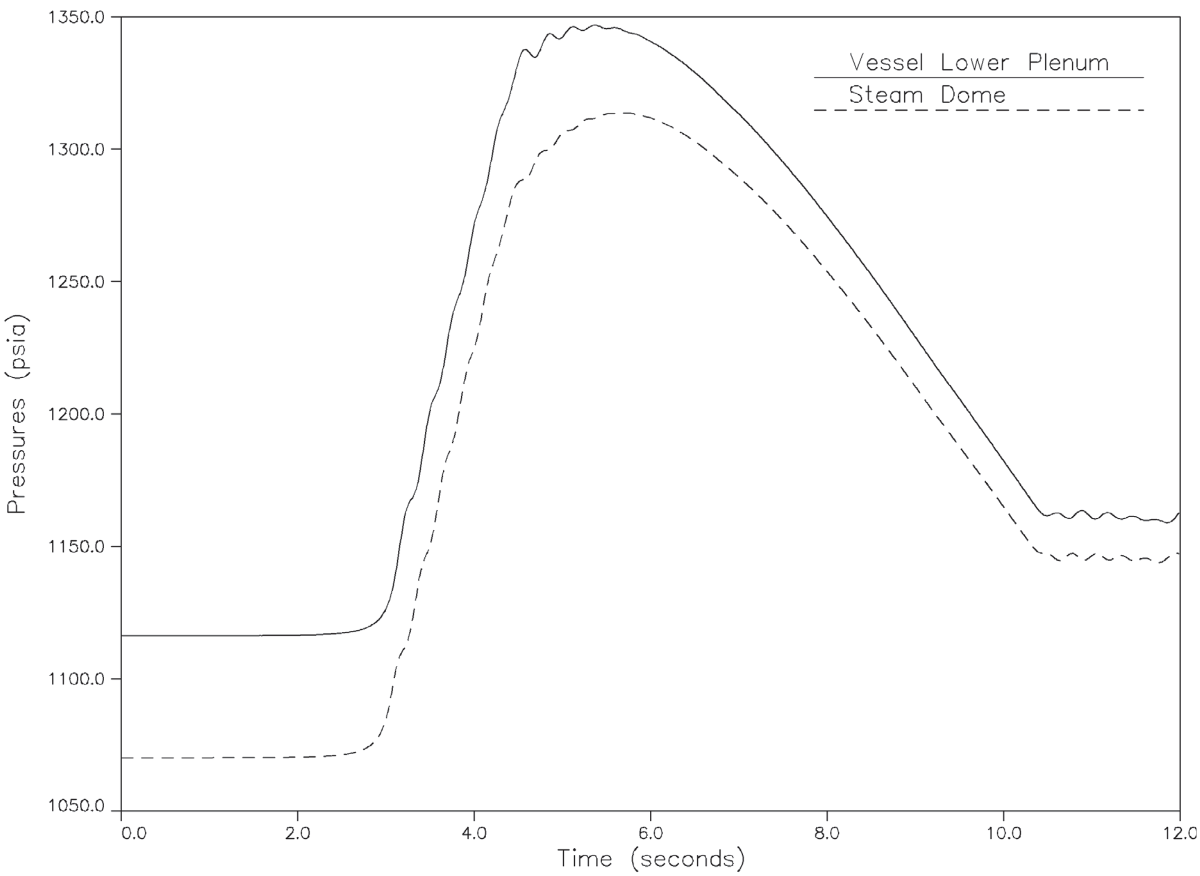

Figure 7.3 MSIV Closure Overpressurization Event at 102P / 105F – Vessel Pressures

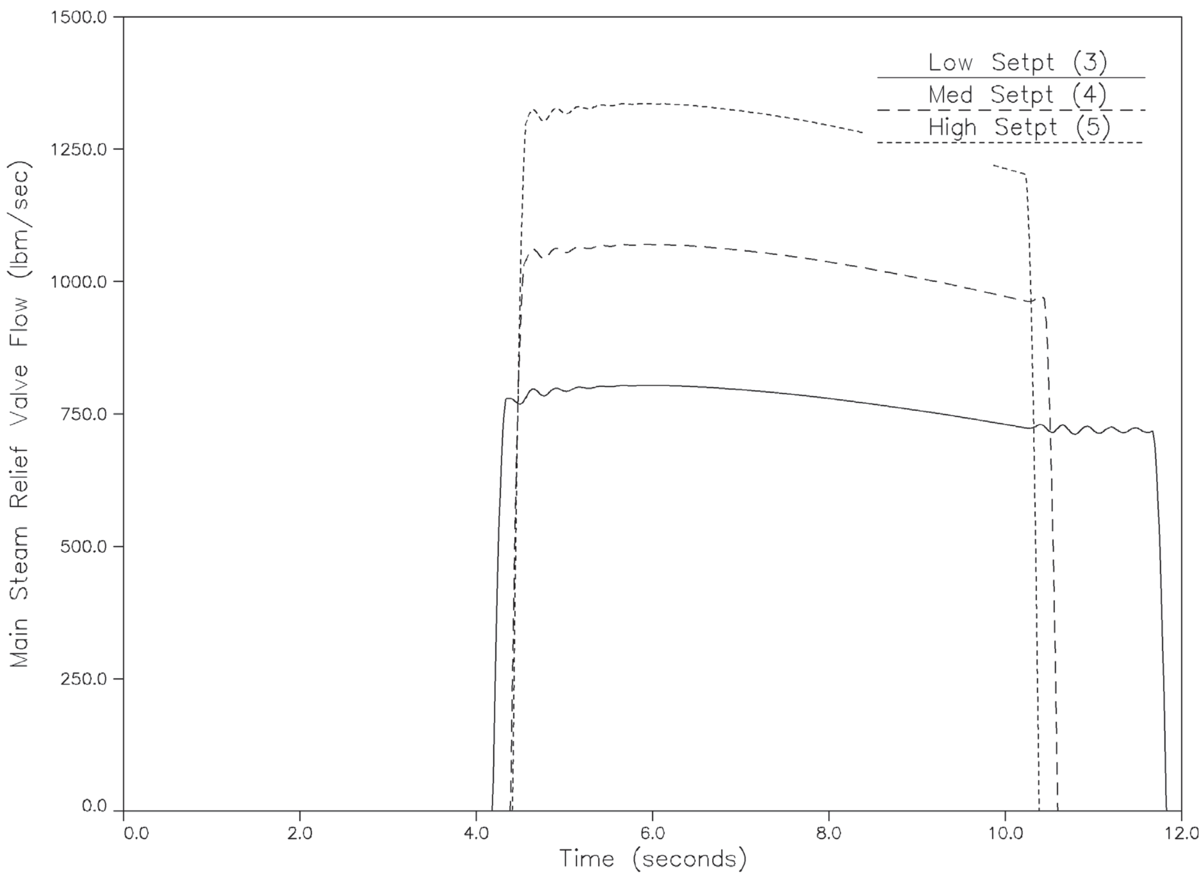

Figure 7.4 MSIV Closure Overpressurization Event at 102P / 105F – Safety / Relief Valve Flow Rates

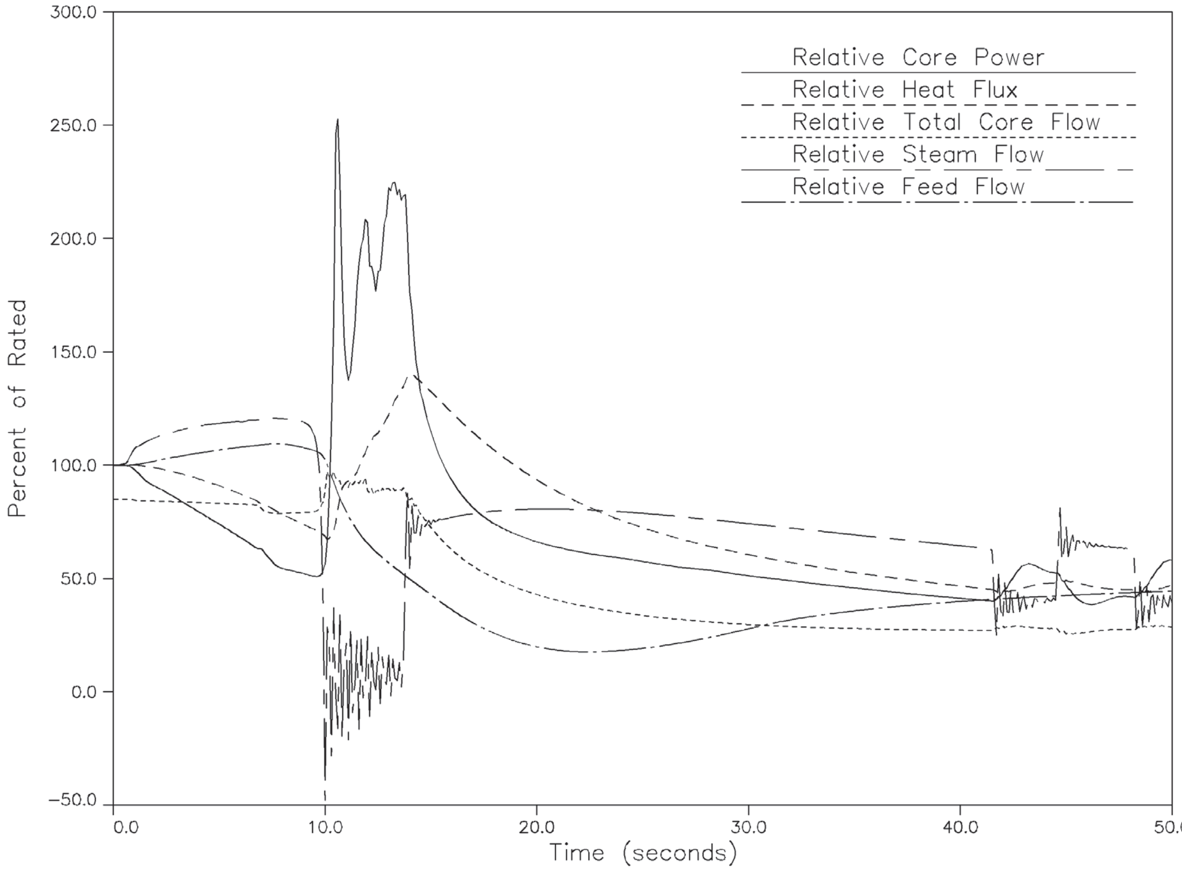

Figure 7.5 PRFO ATWS Overpressurization Event at 100P / 85F – Key Parameters

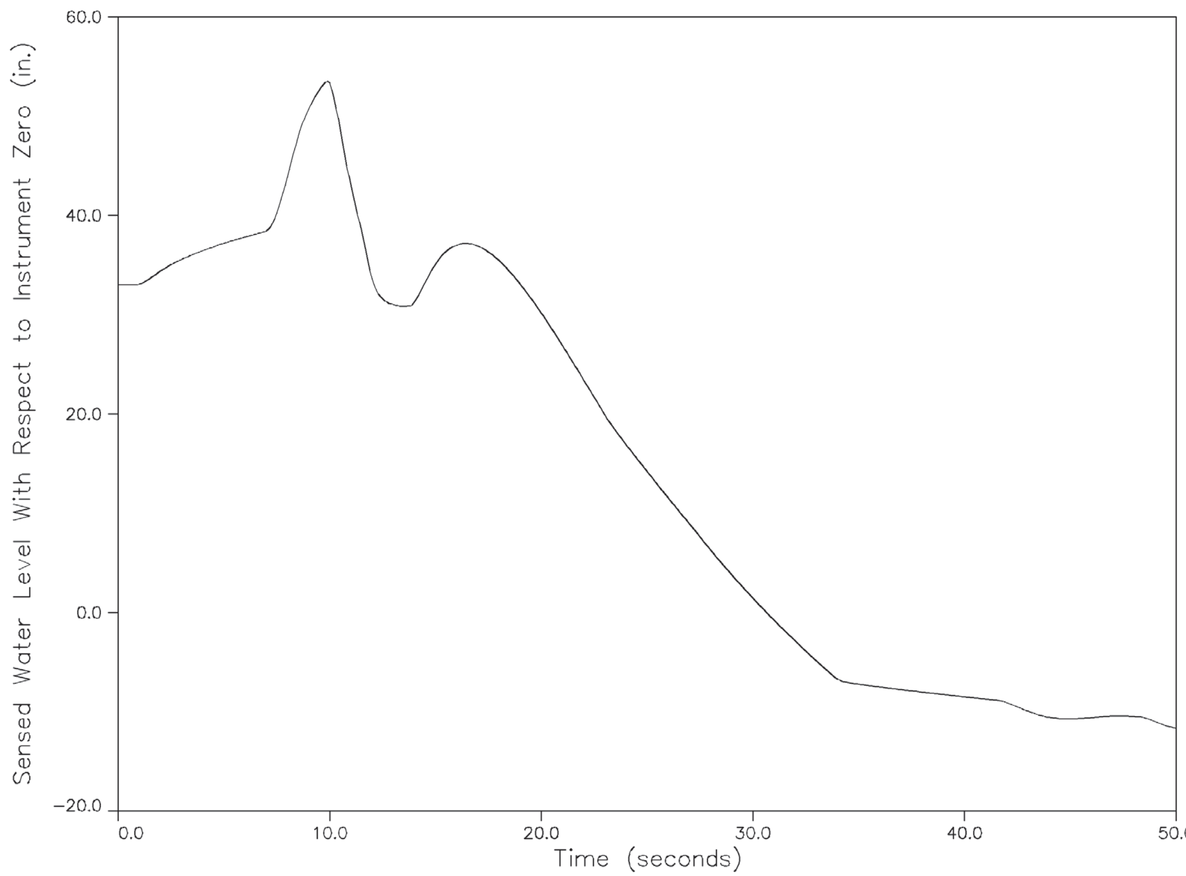

Figure 7.6 PRFO ATWS Overpressurization Event at 100P / 85F – Sensed Water Level

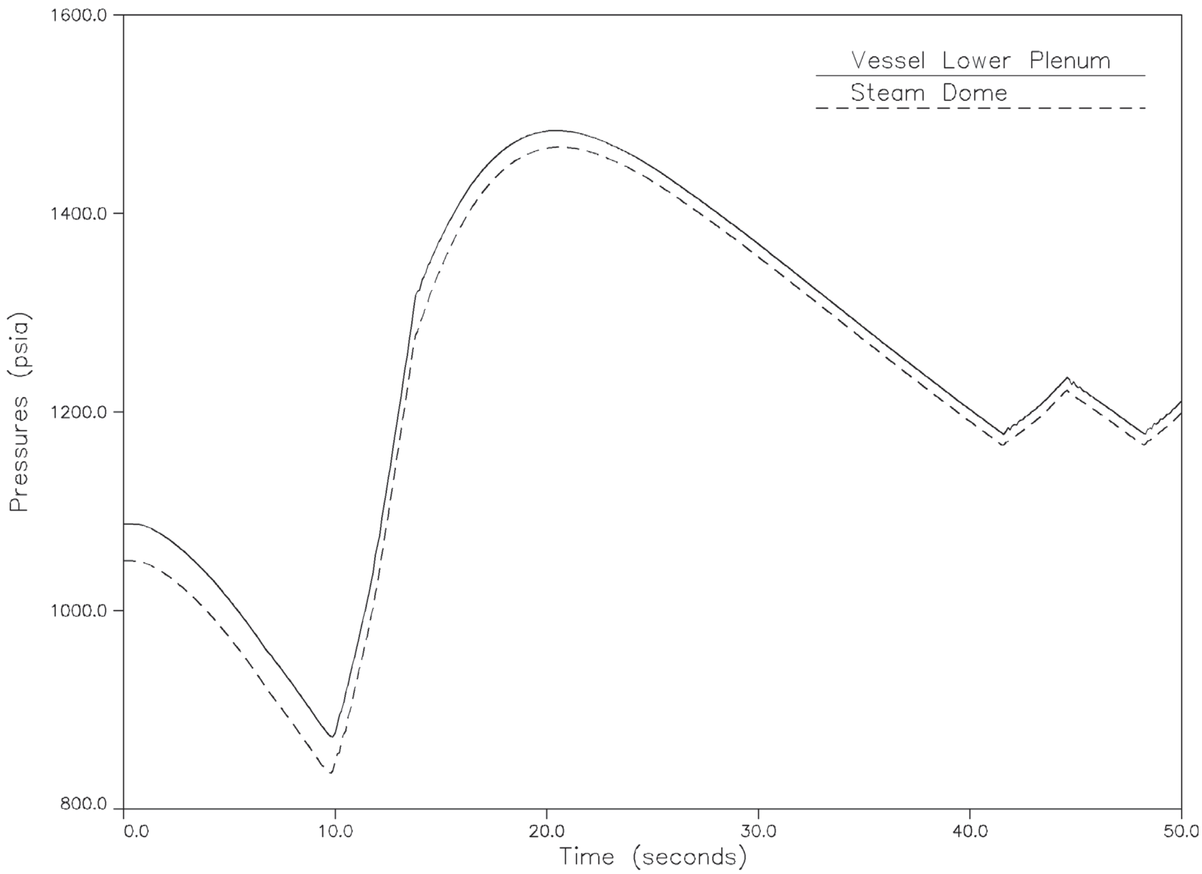

Figure 7.7 PRFO ATWS Overpressurization Event at 100P / 85F – Vessel Pressures

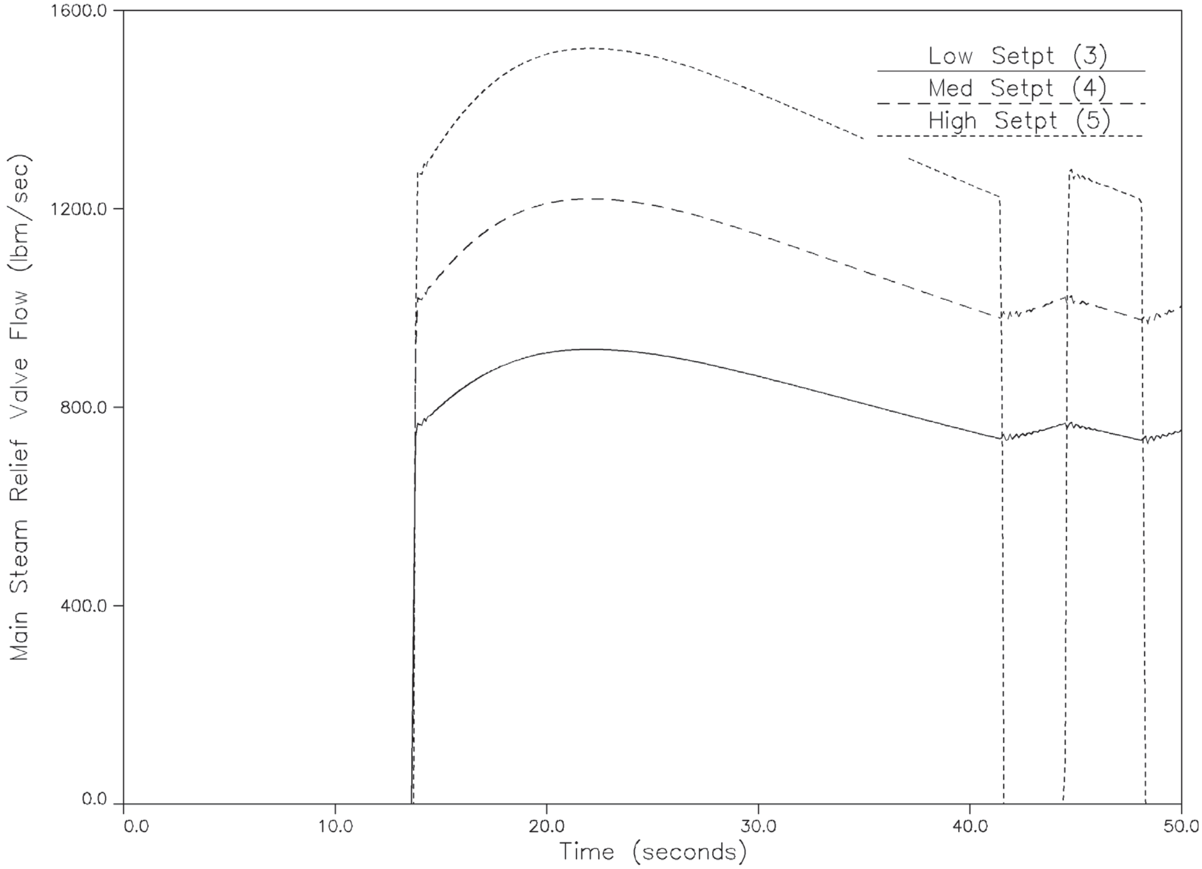

Figure 7.8 PRFO ATWS Overpressurization Event at 100P / 85F – Safety / Relief Valve Flow Rates

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 the Technical Specifications TLO SLMCPR of 1.06 and 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 Table 8.1 – Table 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 present 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. The $MCPR_f$ 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 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 $LHGRFAC_p$ multipliers are determined using the RODEX4 thermal-mechanical methodology (Reference 40). $LHGRFAC_p$ 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*

MAPLHGR limits are discussed in Reference 31. 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	
		ATRIUM 10XM	ATRIUM 11	ATRIUM 10XM	ATRIUM 11	ATRIUM 10XM	ATRIUM 11
Base case operation	100.0	1.38†	1.38	1.42	1.43	1.46	1.46
	90.0	1.44	1.44	1.45	1.46	1.51	1.51
	77.6	1.52	1.52	1.53	1.53	1.58	1.59
	65.0	1.58	1.59	1.60	1.60	1.66	1.66
	> 50.0	1.67	1.73	1.68	1.73	1.76	1.81
	≤ 50.0	1.82	1.91	1.82	1.91	1.84	1.91
	40.0	1.92	1.99	1.92	1.99	1.94	2.03
	26.0	2.26	2.51	2.26	2.51	2.39	2.66
	26.0 at > 50 % F	2.47	2.68	2.47	2.68	2.59	2.81
	23.0 at > 50 % F	2.62	2.93	2.62	2.93	2.76	3.05
	26.0 at ≤ 50 % F	2.38	2.63	2.38	2.63	2.49	2.72
	23.0 at ≤ 50 % F	2.52	2.93	2.52	2.93	2.65	3.05
FHOOS‡	100.0	1.43	1.43	1.46	1.46	---	---
	90.0	1.49	1.49	1.51	1.51	---	---
	77.6	1.55	1.57	1.58	1.59	---	---
	65.0	1.64	1.64	1.66	1.66	---	---
	> 50.0	1.74	1.81	1.76	1.81	---	---
	≤ 50.0	1.83	1.91	1.84	1.91	---	---
	40.0	1.93	2.03	1.94	2.03	---	---
	26.0	2.38	2.66	2.39	2.66	---	---
	26.0 at > 50 % F	2.58	2.81	2.59	2.81	---	---
	23.0 at > 50 % F	2.75	3.05	2.76	3.05	---	---
	26.0 at ≤ 50 % F	2.48	2.72	2.49	2.72	---	---
	23.0 at ≤ 50 % F	2.64	3.05	2.65	3.05	---	---

* 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.

† The BOC to NEOC OSS limit set assumes an RBM set point ≤ 114 %.

‡ Note feedwater heaters out-of-service / FFTR and single-loop operation conditions are not allowed when operating in the MELLLA+ operating domain.

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	
		ATRIUM 10XM	ATRIUM 11	ATRIUM 10XM	ATRIUM 11	ATRIUM 10XM	ATRIUM 11
Base case operation	100.0	1.43	1.43	1.45	1.45	1.51	1.51
	90.0	1.48	1.48	1.49	1.49	1.56	1.56
	77.6	1.56	1.56	1.56	1.56	1.62	1.64
	65.0	1.62	1.62	1.63	1.63	1.69	1.72
	> 50.0	1.70	1.76	1.71	1.76	1.79	1.84
	≤ 50.0	1.83	1.92	1.83	1.92	1.86	1.92
	40.0	1.93	2.00	1.93	2.00	1.96	2.06
	26.0	2.29	2.55	2.29	2.55	2.43	2.69
	26.0 at > 50 % F	2.48	2.68	2.48	2.68	2.61	2.81
	23.0 at > 50 % F	2.63	2.93	2.63	2.93	2.78	3.05
	26.0 at ≤ 50 % F	2.39	2.63	2.39	2.63	2.51	2.72
	23.0 at ≤ 50 % F	2.53	2.93	2.53	2.93	2.67	3.05
TBVOOS	100.0	1.48	1.48	1.52	1.52	1.56	1.56
	90.0	1.53	1.53	1.55	1.55	1.61	1.61
	77.6	1.60	1.60	1.62	1.62	1.68	1.68
	65.0	1.67	1.67	1.69	1.69	1.75	1.75
	> 50.0	1.75	1.78	1.77	1.78	1.85	1.87
	≤ 50.0	1.85	1.92	1.86	1.92	1.89	1.92
	40.0	1.95	2.00	1.96	2.00	1.99	2.06
	26.0	2.32	2.55	2.33	2.55	2.47	2.69
	26.0 at > 50 % F	3.04	3.28	3.05	3.28	3.19	3.38
	23.0 at > 50 % F	3.28	3.57	3.29	3.57	3.42	3.69
	26.0 at ≤ 50 % F	2.79	3.04	2.80	3.04	2.94	3.16
	23.0 at ≤ 50 % F	3.04	3.32	3.05	3.32	3.22	3.56
FHOOS†	100.0	1.48	1.50	1.51	1.51	---	---
	90.0	1.54	1.55	1.56	1.56	---	---
	77.6	1.60	1.64	1.62	1.64	---	---
	65.0	1.68	1.72	1.69	1.72	---	---
	> 50.0	1.78	1.84	1.79	1.84	---	---
	≤ 50.0	1.85	1.92	1.86	1.92	---	---
	40.0	1.95	2.06	1.96	2.06	---	---
	26.0	2.42	2.69	2.43	2.69	---	---
	26.0 at > 50 % F	2.60	2.81	2.61	2.81	---	---
	23.0 at > 50 % F	2.77	3.05	2.78	3.05	---	---
	26.0 at ≤ 50 % F	2.50	2.72	2.51	2.72	---	---
	23.0 at ≤ 50 % F	2.66	3.05	2.67	3.05	---	---
PLUOOS	100.0	1.43	1.43	1.45	1.45	1.51	1.51
	90.0	1.48	1.48	1.49	1.49	1.56	1.56
	77.6	1.56	1.66	1.56	1.66	1.62	1.70
	65.0	1.75	1.83	1.75	1.83	1.78	1.83
	> 50.0	---	---	---	---	---	---
	≤ 50.0	1.83	1.92	1.83	1.92	1.86	1.92
	40.0	1.93	2.00	1.93	2.00	1.96	2.06
	26.0	2.29	2.55	2.29	2.55	2.43	2.69
	26.0 at > 50 % F	2.48	2.68	2.48	2.68	2.61	2.81
	23.0 at > 50 % F	2.63	2.93	2.63	2.93	2.78	3.05
	26.0 at ≤ 50 % F	2.39	2.63	2.39	2.63	2.51	2.72
	23.0 at ≤ 50 % F	2.53	2.93	2.53	2.93	2.67	3.05

* 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.

† Note feedwater heaters out-of-service / FFTR and single-loop operation conditions are not allowed when operating in the MELLLA+ operating domain.

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	
		ATRIUM 10XM	ATRIUM 11	ATRIUM 10XM	ATRIUM 11	ATRIUM 10XM	ATRIUM 11
TBVOOS and FHOOS†	100.0	1.54	1.54	1.56	1.56	---	---
	90.0	1.59	1.59	1.61	1.61	---	---
	77.6	1.66	1.67	1.68	1.68	---	---
	65.0	1.74	1.75	1.75	1.75	---	---
	> 50.0	1.83	1.87	1.85	1.87	---	---
	≤ 50.0	1.88	1.92	1.89	1.92	---	---
	40.0	1.98	2.06	1.99	2.06	---	---
	26.0	2.46	2.69	2.47	2.69	---	---
	26.0 at > 50 % F	3.18	3.38	3.19	3.38	---	---
	23.0 at > 50 % F	3.41	3.69	3.42	3.69	---	---
	26.0 at ≤ 50 % F	2.93	3.16	2.94	3.16	---	---
	23.0 at ≤ 50 % F	3.21	3.56	3.22	3.56	---	---
TBVOOS and PLUOOS	100.0	1.48	1.48	1.52	1.52	1.56	1.56
	90.0	1.53	1.53	1.55	1.55	1.61	1.61
	77.6	1.60	1.68	1.62	1.69	1.68	1.72
	65.0	1.77	1.83	1.78	1.83	1.81	1.83
	> 50.0	---	---	---	---	---	---
	≤ 50.0	1.85	1.92	1.86	1.92	1.89	1.92
	40.0	1.95	2.00	1.96	2.00	1.99	2.06
	26.0	2.32	2.55	2.33	2.55	2.47	2.69
	26.0 at > 50 % F	3.04	3.28	3.05	3.28	3.19	3.38
	23.0 at > 50 % F	3.28	3.57	3.29	3.57	3.42	3.69
	26.0 at ≤ 50 % F	2.79	3.04	2.80	3.04	2.94	3.16
	23.0 at ≤ 50 % F	3.04	3.32	3.05	3.32	3.22	3.56
FHOOS† and PLUOOS	100.0	1.48	1.50	1.51	1.51	---	---
	90.0	1.54	1.55	1.56	1.56	---	---
	77.6	1.60	1.69	1.62	1.70	---	---
	65.0	1.77	1.83	1.78	1.83	---	---
	> 50.0	---	---	---	---	---	---
	≤ 50.0	1.85	1.92	1.86	1.92	---	---
	40.0	1.95	2.06	1.96	2.06	---	---
	26.0	2.42	2.69	2.43	2.69	---	---
	26.0 at > 50 % F	2.60	2.81	2.61	2.81	---	---
	23.0 at > 50 % F	2.77	3.05	2.78	3.05	---	---
	26.0 at ≤ 50 % F	2.50	2.72	2.51	2.72	---	---
	23.0 at ≤ 50 % F	2.66	3.05	2.67	3.05	---	---
TBVOOS, FHOOS,† and PLUOOS	100.0	1.54	1.54	1.56	1.56	---	---
	90.0	1.59	1.59	1.61	1.61	---	---
	77.6	1.66	1.71	1.68	1.72	---	---
	65.0	1.80	1.83	1.81	1.83	---	---
	> 50.0	---	---	---	---	---	---
	≤ 50.0	1.88	1.92	1.89	1.92	---	---
	40.0	1.98	2.06	1.99	2.06	---	---
	26.0	2.46	2.69	2.47	2.69	---	---
	26.0 at > 50 % F	3.18	3.38	3.19	3.38	---	---
	23.0 at > 50 % F	3.41	3.69	3.42	3.69	---	---
	26.0 at ≤ 50 % F	2.93	3.16	2.94	3.16	---	---
	23.0 at ≤ 50 % F	3.21	3.56	3.22	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. BOC to End of COAST limits also support operation with FFTR / FHOOS which bounds operation with feedwater heaters in-service.

† Note feedwater heaters out-of-service / FFTR and single-loop operation conditions are not allowed when operating in the MELLLA+ operating domain.

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	
		ATRIUM 10XM	ATRIUM 11	ATRIUM 10XM	ATRIUM 11	ATRIUM 10XM	ATRIUM 11
Base case operation	100.0	1.48	1.48	1.50	1.50	1.55	1.56
	90.0	1.53	1.53	1.53	1.53	1.60	1.61
	77.6	1.60	1.60	1.60	1.60	1.66	1.70
	65.0	1.66	1.67	1.66	1.67	1.73	1.78
	> 50.0	1.74	1.79	1.74	1.79	1.83	1.90
	≤ 50.0	1.86	1.93	1.86	1.93	1.89	1.93
	40.0	1.96	2.01	1.96	2.01	1.99	2.08
	26.0	2.33	2.57	2.33	2.57	2.48	2.72
	26.0 at > 50 % F	2.50	2.68	2.50	2.68	2.63	2.81
	23.0 at > 50 % F	2.65	2.93	2.65	2.93	2.80	3.05
	26.0 at ≤ 50 % F	2.41	2.63	2.41	2.63	2.53	2.72
	23.0 at ≤ 50 % F	2.55	2.93	2.55	2.93	2.69	3.05
TBVOOS	100.0	1.54	1.54	1.57	1.57	1.61	1.61
	90.0	1.59	1.59	1.60	1.60	1.65	1.65
	77.6	1.66	1.67	1.66	1.67	1.72	1.74
	65.0	1.72	1.74	1.72	1.74	1.79	1.82
	> 50.0	1.79	1.83	1.80	1.83	1.88	---
	≤ 50.0	1.89	1.93	1.89	1.93	1.92	1.93
	40.0	1.99	2.01	1.99	2.01	2.03	2.09
	26.0	2.38	2.57	2.38	2.57	2.51	2.72
	26.0 at > 50 % F	3.07	3.28	3.07	3.28	3.21	3.38
	23.0 at > 50 % F	3.31	3.57	3.31	3.57	3.44	3.69
	26.0 at ≤ 50 % F	2.82	3.04	2.82	3.04	2.96	3.16
	23.0 at ≤ 50 % F	3.07	3.32	3.07	3.32	3.24	3.56
FHOOS†	100.0	1.53	1.56	1.55	1.56	---	---
	90.0	1.59	1.61	1.60	1.61	---	---
	77.6	1.64	1.70	1.66	1.70	---	---
	65.0	1.72	1.78	1.73	1.78	---	---
	> 50.0	1.82	1.90	1.83	1.90	---	---
	≤ 50.0	1.88	1.93	1.89	1.93	---	---
	40.0	1.98	2.08	1.99	2.08	---	---
	26.0	2.47	2.72	2.48	2.72	---	---
	26.0 at > 50 % F	2.62	2.81	2.63	2.81	---	---
	23.0 at > 50 % F	2.79	3.05	2.80	3.05	---	---
	26.0 at ≤ 50 % F	2.52	2.72	2.53	2.72	---	---
	23.0 at ≤ 50 % F	2.68	3.05	2.69	3.05	---	---
PLUOOS	100.0	1.48	1.48	1.50	1.50	1.55	1.56
	90.0	1.53	1.53	1.53	1.53	1.60	1.61
	77.6	1.60	1.69	1.60	1.69	1.66	1.73
	65.0	1.78	1.84	1.78	1.84	1.81	1.84
	> 50.0	---	---	---	---	---	---
	≤ 50.0	1.86	1.93	1.86	1.93	1.89	1.93
	40.0	1.96	2.01	1.96	2.01	1.99	2.08
	26.0	2.33	2.57	2.33	2.57	2.48	2.72
	26.0 at > 50 % F	2.50	2.68	2.50	2.68	2.63	2.81
	23.0 at > 50 % F	2.65	2.93	2.65	2.93	2.80	3.05
	26.0 at ≤ 50 % F	2.41	2.63	2.41	2.63	2.53	2.72
	23.0 at ≤ 50 % F	2.55	2.93	2.55	2.93	2.69	3.05

* 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.

† Note feedwater heaters out-of-service / FFTR and single-loop operation conditions are not allowed when operating in the MELLLA+ operating domain.

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	
		ATRIUM 10XM	ATRIUM 11	ATRIUM 10XM	ATRIUM 11	ATRIUM 10XM	ATRIUM 11
TBVOOS and FHOOS†	100.0	1.59	1.60	1.61	1.61	---	---
	90.0	1.64	1.65	1.65	1.65	---	---
	77.6	1.70	1.74	1.72	1.74	---	---
	65.0	1.78	1.82	1.79	1.82	---	---
	> 50.0	1.87	---	1.88	---	---	---
	≤ 50.0	1.91	1.93	1.92	1.93	---	---
	40.0	2.02	2.09	2.03	2.09	---	---
	26.0	2.50	2.72	2.51	2.72	---	---
	26.0 at > 50 % F	3.20	3.38	3.21	3.38	---	---
	23.0 at > 50 % F	3.43	3.69	3.44	3.69	---	---
	26.0 at ≤ 50 % F	2.95	3.16	2.96	3.16	---	---
	23.0 at ≤ 50 % F	3.23	3.56	3.24	3.56	---	---
TBVOOS and PLUOOS	100.0	1.54	1.54	1.57	1.57	1.61	1.61
	90.0	1.59	1.59	1.60	1.60	1.65	1.65
	77.6	1.66	1.72	1.66	1.72	1.72	1.75
	65.0	1.81	1.84	1.81	1.84	1.84	1.84
	> 50.0	---	---	---	---	---	---
	≤ 50.0	1.89	1.93	1.89	1.93	1.92	1.93
	40.0	1.99	2.01	1.99	2.01	2.03	2.09
	26.0	2.38	2.57	2.38	2.57	2.51	2.72
	26.0 at > 50 % F	3.07	3.28	3.07	3.28	3.21	3.38
	23.0 at > 50 % F	3.31	3.57	3.31	3.57	3.44	3.69
	26.0 at ≤ 50 % F	2.82	3.04	2.82	3.04	2.96	3.16
	23.0 at ≤ 50 % F	3.07	3.32	3.07	3.32	3.24	3.56
FHOOS† and PLUOOS	100.0	1.53	1.56	1.55	1.56	---	---
	90.0	1.59	1.61	1.60	1.61	---	---
	77.6	1.64	1.73	1.66	1.73	---	---
	65.0	1.80	1.84	1.81	1.84	---	---
	> 50.0	---	---	---	---	---	---
	≤ 50.0	1.88	1.93	1.89	1.93	---	---
	40.0	1.98	2.08	1.99	2.08	---	---
	26.0	2.47	2.72	2.48	2.72	---	---
	26.0 at > 50 % F	2.62	2.81	2.63	2.81	---	---
	23.0 at > 50 % F	2.79	3.05	2.80	3.05	---	---
	26.0 at ≤ 50 % F	2.52	2.72	2.53	2.72	---	---
	23.0 at ≤ 50 % F	2.68	3.05	2.69	3.05	---	---
TBVOOS, FHOOS,† and PLUOOS	100.0	1.59	1.60	1.61	1.61	---	---
	90.0	1.64	1.65	1.65	1.65	---	---
	77.6	1.70	1.75	1.72	1.75	---	---
	65.0	1.83	1.84	1.84	1.84	---	---
	> 50.0	---	---	---	---	---	---
	≤ 50.0	1.91	1.93	1.92	1.93	---	---
	40.0	2.02	2.09	2.03	2.09	---	---
	26.0	2.50	2.72	2.51	2.72	---	---
	26.0 at > 50 % F	3.20	3.38	3.21	3.38	---	---
	23.0 at > 50 % F	3.43	3.69	3.44	3.69	---	---
	26.0 at ≤ 50 % F	2.95	3.16	2.96	3.16	---	---
	23.0 at ≤ 50 % F	3.23	3.56	3.24	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. BOC to End of COAST limits also support operation with FFTR / FHOOS which bounds operation with feedwater heaters in-service.

† Note feedwater heaters out-of-service / FFTR and single-loop operation conditions are not allowed when operating in the MELLLA+ operating domain.

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	
		ATRIUM 10XM	ATRIUM 11	ATRIUM 10XM	ATRIUM 11	ATRIUM 10XM	ATRIUM 11
Startup FHOOS 1 TBVIS†	100.0	1.48	1.50	1.51	1.51	1.51	1.51
	90.0	1.54	1.55	1.56	1.56	1.56	1.56
	77.6	1.60	1.69	1.62	1.70	1.62	1.70
	65.0	1.77	1.83	1.78	1.83	1.78	1.83
	> 50.0	---	---	---	---	---	---
	≤ 50.0	1.94	2.02	1.95	2.02	1.95	2.02
	40.0	2.11	2.29	2.12	2.29	2.12	2.29
	26.0	2.68	3.07	2.69	3.07	2.69	3.07
	26.0 at > 50 % F	2.85	3.12	2.86	3.12	2.86	3.12
	23.0 at > 50 % F	3.06	3.42	3.07	3.42	3.07	3.42
	26.0 at ≤ 50 % F	2.74	3.07	2.75	3.07	2.75	3.07
	23.0 at ≤ 50 % F	2.93	3.37	2.94	3.37	2.94	3.37
Startup FHOOS 1 TBVOOS†	100.0	1.54	1.54	1.56	1.56	1.56	1.56
	90.0	1.59	1.59	1.61	1.61	1.61	1.61
	77.6	1.66	1.71	1.68	1.72	1.68	1.72
	65.0	1.80	1.83	1.81	1.83	1.81	1.83
	> 50.0	---	---	---	---	---	---
	≤ 50.0	1.97	2.02	1.98	2.02	1.98	2.02
	40.0	2.14	2.29	2.15	2.29	2.15	2.29
	26.0	2.71	3.07	2.72	3.07	2.72	3.07
	26.0 at > 50 % F	3.36	3.60	3.37	3.60	3.37	3.60
	23.0 at > 50 % F	3.62	4.00	3.63	4.00	3.63	4.00
	26.0 at ≤ 50 % F	3.12	3.39	3.13	3.39	3.13	3.39
	23.0 at ≤ 50 % F	3.42	3.89	3.43	3.89	3.43	3.89

* 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 including TBVOOS. TBVOOS limits are applicable for all EOOS scenarios presented in Table 1.1. Startup FHOOS 1 temperatures are presented as FW Set 1 in Item 6.6.1 of Reference 28. Note feedwater heaters out-of-service / FFTR and single-loop operation conditions are not allowed when operating in the MELLLA+ operating domain.

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	
		ATRIUM 10XM	ATRIUM 11	ATRIUM 10XM	ATRIUM 11	ATRIUM 10XM	ATRIUM 11
Startup FHOOS 2 TBVIS†	100.0	1.48	1.50	1.51	1.51	1.51	1.51
	90.0	1.54	1.55	1.56	1.56	1.56	1.56
	77.6	1.60	1.69	1.62	1.70	1.62	1.70
	65.0	1.77	1.83	1.78	1.83	1.78	1.83
	> 50.0	---	---	---	---	---	---
	≤ 50.0	1.95	2.02	1.96	2.02	1.96	2.02
	40.0	2.12	2.30	2.13	2.30	2.13	2.30
	26.0	2.70	3.09	2.71	3.09	2.71	3.09
	26.0 at > 50 % F	2.86	3.14	2.87	3.14	2.87	3.14
	23.0 at > 50 % F	3.08	3.44	3.09	3.44	3.09	3.44
	26.0 at ≤ 50 % F	2.75	3.09	2.76	3.09	2.76	3.09
	23.0 at ≤ 50 % F	2.95	3.39	2.96	3.39	2.96	3.39
Startup FHOOS 2 TBVOOS†	100.0	1.54	1.54	1.56	1.56	1.56	1.56
	90.0	1.59	1.59	1.61	1.61	1.61	1.61
	77.6	1.66	1.71	1.68	1.72	1.68	1.72
	65.0	1.80	1.83	1.81	1.83	1.81	1.83
	> 50.0	---	---	---	---	---	---
	≤ 50.0	1.98	2.02	1.99	2.02	1.99	2.02
	40.0	2.15	2.30	2.16	2.30	2.16	2.30
	26.0	2.73	3.09	2.74	3.09	2.74	3.09
	26.0 at > 50 % F	3.38	3.62	3.39	3.62	3.39	3.62
	23.0 at > 50 % F	3.63	4.02	3.64	4.02	3.64	4.02
	26.0 at ≤ 50 % F	3.13	3.40	3.14	3.40	3.14	3.40
	23.0 at ≤ 50 % F	3.43	3.90	3.44	3.90	3.44	3.90

* 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 including TBVOOS. TBVOOS limits are applicable for all EOOS scenarios presented in Table 1.1. Startup FHOOS 2 temperatures are presented as FW Set 2 in Item 6.6.1 of Reference 28. Note feedwater heaters out-of-service / FFTR and single-loop operation conditions are not allowed when operating in the MELLLA+ operating domain.

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	
		ATRIUM 10XM	ATRIUM 11	ATRIUM 10XM	ATRIUM 11	ATRIUM 10XM	ATRIUM 11
Startup FHOOS 1 TBVIS†	100.0	1.53	1.56	1.55	1.56	1.55	1.56
	90.0	1.59	1.61	1.60	1.61	1.60	1.61
	77.6	1.64	1.73	1.66	1.73	1.66	1.73
	65.0	1.80	1.84	1.81	1.84	1.81	1.84
	> 50.0	---	---	---	---	---	---
	≤ 50.0	1.98	2.04	1.99	2.04	1.99	2.04
	40.0	2.15	2.32	2.16	2.32	2.16	2.32
	26.0	2.73	3.10	2.74	3.10	2.74	3.10
	26.0 at > 50 % F	2.87	3.12	2.88	3.12	2.88	3.12
	23.0 at > 50 % F	3.08	3.42	3.09	3.42	3.09	3.42
	26.0 at ≤ 50 % F	2.76	3.10	2.77	3.10	2.77	3.10
	23.0 at ≤ 50 % F	2.95	3.40	2.96	3.40	2.96	3.40
Startup FHOOS 1 TBVOOS†	100.0	1.59	1.60	1.61	1.61	1.61	1.61
	90.0	1.64	1.65	1.65	1.65	1.65	1.65
	77.6	1.70	1.75	1.72	1.75	1.72	1.75
	65.0	1.83	1.84	1.84	1.84	1.84	1.84
	> 50.0	---	---	---	---	---	---
	≤ 50.0	2.01	2.05	2.02	2.05	2.02	2.05
	40.0	2.19	2.32	2.20	2.32	2.20	2.32
	26.0	2.76	3.10	2.77	3.10	2.77	3.10
	26.0 at > 50 % F	3.38	3.60	3.39	3.60	3.39	3.60
	23.0 at > 50 % F	3.64	4.00	3.65	4.00	3.65	4.00
	26.0 at ≤ 50 % F	3.14	3.39	3.15	3.39	3.15	3.39
	23.0 at ≤ 50 % F	3.44	3.89	3.45	3.89	3.45	3.89

* 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 including TBVOOS. TBVOOS limits are applicable for all EOOS scenarios presented in Table 1.1. Startup FHOOS 1 temperatures are presented as FW Set 1 in Item 6.6.1 of Reference 28. Note feedwater heaters out-of-service / FFTR and single-loop operation conditions are not allowed when operating in the MELLLA+ operating domain.

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	
		ATRIUM 10XM	ATRIUM 11	ATRIUM 10XM	ATRIUM 11	ATRIUM 10XM	ATRIUM 11
Startup FHOOS 2 TBVIS†	100.0	1.53	1.56	1.55	1.56	1.55	1.56
	90.0	1.59	1.61	1.60	1.61	1.60	1.61
	77.6	1.64	1.73	1.66	1.73	1.66	1.73
	65.0	1.80	1.84	1.81	1.84	1.81	1.84
	> 50.0	---	---	---	---	---	---
	≤ 50.0	1.99	2.05	2.00	2.05	2.00	2.05
	40.0	2.16	2.33	2.17	2.33	2.17	2.33
	26.0	2.75	3.12	2.76	3.12	2.76	3.12
	26.0 at > 50 % F	2.88	3.14	2.89	3.14	2.89	3.14
	23.0 at > 50 % F	3.10	3.44	3.11	3.44	3.11	3.44
	26.0 at ≤ 50 % F	2.77	3.12	2.78	3.12	2.78	3.12
	23.0 at ≤ 50 % F	2.97	3.42	2.98	3.42	2.98	3.42
Startup FHOOS 2 TBVOOS†	100.0	1.59	1.60	1.61	1.61	1.61	1.61
	90.0	1.64	1.65	1.65	1.65	1.65	1.65
	77.6	1.70	1.75	1.72	1.75	1.72	1.75
	65.0	1.83	1.84	1.84	1.84	1.84	1.84
	> 50.0	---	---	---	---	---	---
	≤ 50.0	2.02	2.06	2.03	2.06	2.03	2.06
	40.0	2.20	2.33	2.21	2.33	2.21	2.33
	26.0	2.78	3.12	2.79	3.12	2.79	3.12
	26.0 at > 50 % F	3.40	3.62	3.41	3.62	3.41	3.62
	23.0 at > 50 % F	3.65	4.02	3.66	4.02	3.66	4.02
	26.0 at ≤ 50 % F	3.15	3.40	3.16	3.40	3.16	3.40
	23.0 at ≤ 50 % F	3.45	3.90	3.46	3.90	3.46	3.90

* 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 including TBVOOS. TBVOOS limits are applicable for all EOOS scenarios presented in Table 1.1. Startup FHOOS 2 temperatures are presented as FW Set 2 in Item 6.6.1 of Reference 28. Note feedwater heaters out-of-service / FFTR and single-loop operation conditions are not allowed when operating in the MELLLA+ operating domain.

Table 8.6 SLO MCPR$_p$ Limits for All Scram Speeds*

Operating Condition	Power (% of rated)	BOC to End of COAST	
		ATRIUM 10XM	ATRIUM 11
RCPOOS FHOOS†	100.0	2.03	2.05
	43.75	2.03	2.05
	40.0	2.03	2.10
	26.0	2.50	2.74
	26.0 at > 50 % F	2.65	2.83
	23.0 at > 50 % F	2.82	3.07
	26.0 at ≤ 50 % F	2.55	2.74
	23.0 at ≤ 50 % F	2.71	3.07
RCPOOS TBVOOS PLUOOS FHOOS†	100.0	2.03	2.05
	43.75	2.03	2.05
	40.0	2.05	2.11
	26.0	2.53	2.74
	26.0 at > 50 % F	3.23	3.40
	23.0 at > 50 % F	3.46	3.71
	26.0 at ≤ 50 % F	2.98	3.18
	23.0 at ≤ 50 % F	3.26	3.58
RCPOOS TBVOOS FHOOS1	100.0	2.16	2.24
	43.75	2.16	2.24
	40.0	2.22	2.34
	26.0	2.79	3.12
	26.0 at > 50 % F	3.41	3.62
	23.0 at > 50 % F	3.67	4.02
	26.0 at ≤ 50 % F	3.17	3.41
	23.0 at ≤ 50 % F	3.47	3.91
RCPOOS TBVOOS FHOOS2	100.0	2.17	2.25
	43.75	2.17	2.25
	40.0	2.23	2.35
	26.0	2.81	3.14
	26.0 at > 50 % F	3.43	3.64
	23.0 at > 50 % F	3.68	4.04
	26.0 at ≤ 50 % F	3.18	3.42
	23.0 at ≤ 50 % F	3.48	3.92

* 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 43.75 % core power, 50 % core flow, and an active recirculation drive flow of 17.73 Mlb/hr.

† Note feedwater heaters out-of-service / FFTR and single-loop operation conditions are not allowed when operating in the MELLLA+ operating domain.

Table 8.7 $MCPR_f$ Limits for All Fuel Types

Core Flow (% of rated)	$MCPR_f$
30.0	1.58
84.0	1.34
107.0	1.34

Table 8.8 Steady-State LHGR Limits

Peak Pellet Exposure (GWd/MTU)	ATRIUM 10XM (kW/ft)	ATRIUM 11 (kW/ft)
0.0	14.1	12.2
18.9	14.1	12.2
74.4	7.4	6.4

Table 8.9 LHGRFAC$_p$ Multipliers*

EOOS Condition	Power (% rated)	Base case operation (TBVIS)[†] LHGRFAC$_p$		TBVOOS[‡] LHGRFAC$_p$	
		ATRIUM 10XM	ATRIUM 11	ATRIUM 10XM	ATRIUM 11
Nominal operation and FHOOS[§]	100.0	1.00	1.00	1.00	1.00
	26.0	0.63	0.61	0.62	0.60
	26.0 at > 50 % F	0.47	0.44	0.39	0.38
	23.0 at > 50 % F	0.43	0.42	0.36	0.34
	26.0 at ≤ 50 % F	0.51	0.48	0.50	0.48
	23.0 at ≤ 50 % F	0.49	0.45	0.44	0.43
Startup FHOOS 1[§]	100.0	1.00	1.00	1.00	1.00
	26.0	0.54	0.51	0.53	0.51
	26.0 at > 50 % F	0.41	0.39	0.36	0.34
	23.0 at > 50 % F	0.38	0.36	0.32	0.31
	26.0 at ≤ 50 % F	0.45	0.41	0.42	0.41
	23.0 at ≤ 50 % F	0.44	0.41	0.40	0.38
Startup FHOOS 2[§]	100.0	1.00	1.00	1.00	1.00
	26.0	0.54	0.51	0.53	0.51
	26.0 at > 50 % F	0.40	0.39	0.35	0.34
	23.0 at > 50 % F	0.38	0.35	0.32	0.30
	26.0 at ≤ 50 % F	0.45	0.41	0.42	0.41
	23.0 at ≤ 50 % F	0.43	0.40	0.40	0.38

* 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 including 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 28. Startup FHOOS 1 and Startup FHOOS 2 temperatures are presented as FW Set 1 and FW Set 2, respectively, in Item 6.6.1 of Reference 28.

Table 8.10 LHGRFAC$_f$ Multipliers for All Fuel Types

Core Flow (% of rated)	LHGRFAC$_f$
0.0	0.63
30.0	0.63
76.4	1.00
107.0	1.00

Table 8.11 MAPLHGR Limits

Average Planar Exposure (GWd/MTU)	ATRIUM 10XM (kW/ft)	ATRIUM 11 (kW/ft)
0.0	13.0	10.0
10.0	---	10.0
15.0	13.0	---
67.0	7.6	5.9

9.0 REFERENCES

1. ANP-3865P Revision 0, *Browns Ferry Unit 2 Cycle 22 Fuel Cycle Design Report,* Framatome Inc., August 2020.

2. FS1-0035055 Revision 1.0, "Browns Ferry Disposition of Events at EPU Conditions," Framatome Inc., January 2018.

3. FS1-0050073 Revision 1.0, "Browns Ferry Unit 2 Cycle 22 Calculation Plan," Framatome Inc., June 2020.

4. ANP-3150P Revision 4, *Mechanical Design Report for Browns Ferry ATRIUM 10XM Fuel Assemblies,* AREVA Inc., November 2017.

5. ANP-3525P Revision 1, *Fuel Rod Thermal-Mechanical Evaluation for Browns Ferry Unit 2 Cycle 20 Reload BFE2-20*, Framatome Inc., February 2018.

6. ANP-3716P Revision 0, *ATRIUM 10XM Fuel Rod Thermal-Mechanical Evaluation for Browns Ferry Unit 2 Cycle 21,* Framatome Inc., November 2018.

7. ANP-3822P Revision 0, *ATRIUM 10XM Fuel Rod Thermal-Mechanical Evaluation for Browns Ferry Unit 2 Cycle 21 (MELLLA+),* Framatome Inc., January 2020.

8. ANP-3873P Revision 0, *ATRIUM 10XM Fuel Rod Thermal-Mechanical Evaluation for Browns Ferry Unit 2 Cycle 22,* Framatome Inc., September 2020.

9. ANP-3344P Revision 1, *Fuel Rod Thermal-Mechanical Evaluation for Browns Ferry Unit 2 Cycle 19 Reload BFE2-19*, AREVA Inc., December 2014.

10. ANP-3348P Revision 0, *Mechanical Design Report for Browns Ferry Unit 2 Cycle 19 ATRIUM 11 Lead Test Assemblies*, AREVA Inc., November 2014.

11. ANP-3159P Revision 0, *ATRIUM 10XM Fuel Rod Thermal-Mechanical Evaluation for Browns Ferry Unit 2 Cycle 19 Reload BFE2-19*, AREVA NP, October 2012.

12. ANP-3602P Revision 1, *Browns Ferry Thermal-Hydraulic Design Report for ATRIUM 10XM Fuel Assemblies at EPU MELLLA+,* Framatome Inc., June 2019.

13. ANP-10307PA Revision 0, *AREVA MCPR Safety Limit Methodology for Boiling Water Reactors,* AREVA NP, June 2011.

14. ANP-10298PA Revision 0, *ACE/ATRIUM 10XM Critical Power Correlation*, AREVA NP, March 2010.

15. ANP-3140(P) Revision 0, *Browns Ferry Units 1, 2, and 3 Improved K-factor Model for ACE/ATRIUM 10XM Critical Power Correlation*, AREVA NP, August 2012.

16. EMF-2209(P)(A) Revision 3, *SPCB Critical Power Correlation*, AREVA NP, September 2009.

17. NEDO-33075-A Revision 8, *GE Hitachi Nuclear Energy, GE Hitachi Boiling Water Reactor, Detect and Suppress Solution – Confirmation Density*, November 2013. (ADAMS Accession Number ML13324A099)

18. NEDO-33877 Revision 0, Safety Analysis Report for Browns Ferry Nuclear Plant Units 1, 2, and 3 Maximum Extended Load Line Limit Analysis Plus, February 2018. (ADAMS Accession Number ML18079B140)

19. EMF-CC-074(P)(A) Volume 4 Revision 0, *BWR Stability Analysis: Assessment of STAIF with Input from MICROBURN-B2,* Siemens Power Corporation, August 2000.

20. 004N5430 Revision 2, *Browns Ferry Units 1, 2 and 3 – Backup Stability Protection Region Endpoint Determination Procedure and ABSP Setpoints Confirmation, GE Hitachi Nuclear Energy*, April 2018 (FS1-0038489 Revision 1.0).

21. NEDO-33006-A Revision 3, *General Electric Boiling Water Reactor Maximum Extended Load Line Limit Analysis Plus*, General Electric Hitachi Nuclear Energy America, LLC, June 2009. (ADAMS Accession Number ML091800530)

22. EMF-2158(P)(A) Revision 0, *Siemens Power Corporation Methodology for Boiling Water Reactors: Evaluation and Validation of CASMO-4/MICROBURN-B2,* Siemens Power Corporation, October 1999.

23. ANF-913(P)(A) Volume 1 Revision 1 and Volume 1 Supplements 2, 3 and 4, *COTRANSA2: A Computer Program for Boiling Water Reactor Transient Analyses*, Advanced Nuclear Fuels Corporation, August 1990.

24. XN-NF-80-19(P)(A) Volume 3 Revision 2, *Exxon Nuclear Methodology for Boiling Water Reactors, THERMEX: Thermal Limits Methodology Summary Description*, Exxon Nuclear Company, January 1987.

25. XN-NF-84-105(P)(A) Volume 1 and Volume 1 Supplements 1 and 2, *XCOBRA-T: A Computer Code for BWR Transient Thermal-Hydraulic Core Analysis,* Exxon Nuclear Company, February 1987.

26. XN-NF-81-58(P)(A) Revision 2 and Supplements 1 and 2, *RODEX2 Fuel Rod Thermal-Mechanical Response Evaluation Model,* Exxon Nuclear Company, March 1984.

27. *Technical Specification Requirements for Browns Ferry Nuclear Plant Unit 2,* Tennessee Valley Authority, as amended.

28. ANP-3855P Revision 0, *Browns Ferry Unit 2 Cycle 22 Plant Parameters Document*, Framatome Inc., May 2020.

29. ANF-1358(P)(A) Revision 3, *The Loss of Feedwater Heating Transient in Boiling Water Reactors,* Framatome ANP, September 2005.

30. ANP-3546P Revision 0, *Browns Ferry Units 1, 2, and 3 LOCA Break Spectrum Analysis for ATRIUM 10XM Fuel (EPU MELLLA+),* AREVA Inc., March 2017.

31. ANP-3547P Revision 2, *Browns Ferry Units 1, 2, and 3 LOCA-ECCS Analysis MAPLHGR Limits for ATRIUM 10XM Fuel (EPU MELLLA+)*, Framatome Inc., January 2020.

32. FS1-0044279 Revision 1.0, "10 CFR 50.46 PCT Error Report for Browns Ferry Units 1, 2, and 3 with EPU/MELLLA+ Conditions," Framatome Inc., January 2020.

33. XN-NF-80-19(P)(A) Volume 1 and Supplements 1 and 2, *Exxon Nuclear Methodology for Boiling Water Reactors - Neutronic Methods for Design and Analysis*, Exxon Nuclear Company, March 1983.

34. Letter, EA Brown (NRC) to KW Singer (TVA), "Browns Ferry Nuclear Plant, Units 1, 2, and 3 – Issuance of Amendments Regarding Full-Scope Implementation of Alternative Source Term (TAC Nos. MB5733, MB5734, MB5735, MC0156, MC0157 and MC0158) (TS-405)," September 27, 2004.

35. Letter, TA Galioto (FANP) to JF Lemons (TVA), "Fuel Handling Accident Assumptions for Browns Ferry," TAG:02:012, January 23, 2002.

36. XN-NF-80-19(P)(A) Volume 4 Revision 1, *Exxon Nuclear Methodology for Boiling Water Reactors: Application of the ENC Methodology to BWR Reloads*, Exxon Nuclear Company, June 1986.

37. ANP-3404P Revision 3, *Browns Ferry Unit 3 Cycle 19 Representative Reload Analysis at Extended Power Uprate*, AREVA Inc., December 2015.

38. ANP-3307P Revision 1, *AREVA Support of TVA's ECP for Implementation of ATRIUM 11 Into Browns Ferry*, AREVA Inc., November 2014.

39. ANP-3160(P) Revision 1, *Browns Ferry Nuclear Plant Units 1, 2, and 3 Spent Fuel Storage Pool Criticality Safety Analysis for ATRIUM™ 10XM Fuel,* AREVA Inc., December 2015.

40. BAW-10247PA Revision 0, *Realistic Thermal-Mechanical Fuel Rod Methodology for Boiling Water Reactors*, AREVA NP, February 2008.