Brunswick Nuclear Plant
8470 River Rd SE
Southport, NC 28461

Enclosure 4 Contains Proprietary Information
Withhold in Accordance with 10 CFR 2.390

March 27, 2021

Serial: RA-21-0098

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

Subject: Brunswick Steam Electric Plant, Unit No. 2
Renewed Facility Operating License No. DPR-62
Docket No. 50-324
Unit 2 Cycle 25 Core Operating Limits Report (COLR) and Reload Safety Analysis Report (RSAR)

Reference:

1. Letter from Jerry Pierce (Duke Energy) to the U.S. Nuclear Regulatory Commission Document Control Desk, *Unit 2 Cycle 24 Core Operating Limits Report (COLR)*, dated March 19, 2019, ADAMS Accession Number ML19079A038.

2. Letter from William R. Gideon (Duke Energy) to the U.S. Nuclear Regulatory Commission Document Control Desk, *Request for License Amendment Regarding Application of Advanced Framatome Methodologies*, dated October 11, 2018, ADAMS Accession Number ML18284A395.

3. Letter from Andrew Hon (U.S. Nuclear Regulatory Commission) to John A. Krakuszeski (Duke Energy), *Issuance of Amendment Nos. 299 and 327 to Revise Technical Specification 5.6.5b to Allow Application of Advanced Framatome ATRIUM 11 Fuel Methodologies*, dated March 6, 2020, ADAMS Accession Number ML20073F186.

Ladies and Gentlemen:

Enclosure 1 provides a copy of the Core Operating Limits Report (COLR) for Brunswick Steam Electric Plant (BSEP), Unit 2 Cycle 25 operation. Duke Energy Progress, LLC (Duke Energy), is providing the enclosed COLR in accordance with Brunswick Unit 2 Technical Specification 5.6.5.d. The enclosed COLR supersedes the report previously submitted by letter dated March 19, 2019 (i.e., Reference 1).

In addition, as committed to in Reference 2, the BSEP Unit 2 Cycle 25 Reload Safety Analysis Report (i.e., ANP-3897P) is being transmitted to the NRC, for information. This report is included in Enclosure 4. The Reference 2 license amendment request was approved by the Nuclear Regulatory Commission on March 6, 2020 (i.e., Reference 3), revising Unit 1 and Unit 2 Technical Specification 5.6.5.b to allow application of Advanced Framatome Methodologies for determining core operating limits in support of loading Framatome fuel type ATRIUM 11.

Enclosure 4 contains information considered proprietary to Framatome. The proprietary information in this report has been denoted by brackets. As owner of the proprietary information, Framatome has executed the affidavit contained in Enclosure 3 which identifies the information as proprietary, is customarily held in confidence, and should be withheld from public disclosure in accordance with 10 CFR 2.390. Enclosure 2 provides the non-proprietary version of this report.

This letter and its enclosures do not contain any regulatory commitments.

Please refer any questions regarding this submittal to Mr. Stephen Yodersmith, Brunswick Regulatory Affairs, at (910) 832-2568.

Sincerely,

Sabrina Salazar
Manager – Nuclear Support Services
Brunswick Steam Electric Plant

Enclosures:

1. Brunswick Unit 2, Cycle 25 Core Operating Limits Report
2. ANP-3897NP, *Brunswick Unit 2 Cycle 25 Reload Safety Analysis,* Revision 0
3. Affidavit for ANP-3897P
4. ANP-3897P, *Brunswick Unit 2 Cycle 25 Reload Safety Analysis,* Revision 0 **[Proprietary Information – Withhold from Public Disclosure in Accordance with 10 CFR 2.390]**

cc (with all Enclosures):

Ms. Laura Dudes, NRC Regional Administrator, Region II
Mr. Andrew Hon, NRC Project Manager
Mr. Gale Smith, NRC Senior Resident Inspector

cc (with Enclosures 1, 2, and 3 only):

Chair - North Carolina Utilities Commission

Brunswick Unit 2, Cycle 25 Core Operating Limits Report

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Evans, Steve	Originator	3/27/2021
Wells, Ryan E.	Verifier	3/27/2021
LoMonaco, Megan A	Reviewer	3/27/2021
Lambert, Brad	Approver	3/27/2021

Notes :

BRUNSWICK UNIT 2, CYCLE 25

CORE OPERATING LIMITS REPORT

March 2021

Prepared by:	[Signed Electronically] **Steve Evans** **Brunswick Nuclear Design**
Reviewed by:	[Signed Electronically] **Ryan Wells** **Brunswick Nuclear Design**
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Approved by:	[Signed Electronically] **Brad Lambert** **Manager, Brunswick Nuclear Design**

Implementation Instructions for Revision 0

Revision Description

Design Calculation 2B21-2080 Revision 0 documents the initial generation of the B2C25 Core Operating Limits Report in support of the B2C25 Reload Core Design.

Implementation Requirements

Technical Specifications Amendments 327 (Advanced Framatome Methods) and 329 (TSTF-564) are required to be implemented prior to the issuance of the B2C25 COLR Revision 0.

Implementation Schedule

The B2C25 COLR Revision 0 must be issued prior to entering MODE 2 for startup following the Unit 2 Spring 2021 refueling outage.

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References to COLR Figures or Tables should be made using titles only; Figure and Table numbers may change from cycle to cycle.

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CAUTION
References to COLR Figures or Tables should be made using titles only; Figure and Table numbers may change from cycle to cycle.

LIST OF FIGURES

NOMENCLATURE

2PT	Two Recirculation Pump Trip
ΔW	SLO Flow Uncertainty
ABSP	Automated Backup Stability Protection
APLHGR	Average Planar Linear Heat Generation Rate
APRM	Average Power Range Monitor (Subsystem)
ARTS	APRM/RBM Technical Specification
BEO-III	Best-estimate Enhanced Option-III
BOC	Beginning of Cycle
BSP	Backup Stability Protection
BWROG	BWR Owners' Group
CAVEX	Core Average Exposure
CDA	Confirmation Density Algorithm
COLR	Core Operating Limits Report
CRWE	Control Rod Withdrawal Error
ECCS	Emergency Core Cooling System
EFPD	Effective Full Power Day
EOC	End of Cycle
EOCLB	End of Cycle Licensing Basis
EOFP	End of Full Power
EOOS	Equipment Out-of-Service
ESS	Extended SCRAM Speed
F	Flow (Total Core)
FHOOS	Feedwater Heater Out-of-Service
FFTR	Final Feedwater Temperature Reduction
FWTR	Feedwater Temperature Reduction
GE	General Electric
HFCL	High Flow Control Line
HPSP	High Power Set Point
HTSP	High Trip Set Point
ICF	Increased Core Flow
IPSP	Intermediate Power Set Point
ITSP	Intermediate Trip Set Point
LCO	Limiting Condition of Operation
LHGR	Linear Heat Generation Rate
$LHGR_{SS}$	Steady-State Maximum Linear Heat Generation Rate
LHGRFAC	Linear Heat Generation Rate Factor
$LHGRFAC_f$	Flow-Dependent Linear Heat Generation Rate Factor
$LHGRFAC_p$	Power-Dependent Linear Heat Generation Rate Factor
LOCA	Loss of Coolant Accident
LPRM	Local Power Range Monitor (Subsystem)
LPSP	Low Power Set Point
LTSP	Low Trip Set Point

NOMENCLATURE (continued)

MAPLHGR	Maximum Average Planar Linear Heat Generation Rate
$MAPLHGR_{SS}$	Steady-State Maximum Average Planar Linear Heat Generation Rate
MAPFAC	Maximum Average Planar Linear Heat Generation Rate Factor
$MAPFAC_f$	Flow-Dependent Maximum Average Planar Linear Heat Generation Rate Factor
$MAPFAC_p$	Power-Dependent Maximum Average Planar Linear Heat Generation Rate Factor
$MAPFAC_{SLO}$	Maximum Average Planar Linear Heat Generation Rate Factor when in SLO
MCE	Maximum Core Exposure
MCPR	Minimum Critical Power Ratio
$MCPR_{99.9\%}$	Cycle-specific safety limit MCPR that ensures at least 99.9% of fuel rods are not susceptible to boiling transition
$MCPR_f$	Flow-Dependent Minimum Critical Power Ratio
$MCPR_p$	Power-Dependent Minimum Critical Power Ratio
MELLL	Maximum Extended Load Line Limit
MELLLA+	Maximum Extended Load Line Limit Analysis +
MEOD	Maximum Extended Operating Domain
MSIVOOS	Main Steam Isolation Valve Out-of-Service
N/A	Not Applicable
NCL	Natural Circulation Line
NEOC	Near End of Cycle
NFWT	Nominal Feedwater Temperature
NRC	Nuclear Regulatory Commission
NSS	Nominal SCRAM Speed
OLMCPR	Operating Limit Minimum Critical Power Ratio
OPRM	Oscillation Power Range Monitor
OOS	Out-of-Service
P	Power (Total Core Thermal)
PRNM	Power Range Neutron Monitoring (System)
RBM	Rod Block Monitor (Subsystem)
RDF	Rated Drive Flow
RFWT	Reduced Feedwater Temperature
RPT	Recirculation Pump Trip
RTP	Rated Thermal Power
S_{AD}	Amplitude Discriminator Setpoint
SLO	Single Loop Operation
SRV	Safety Relief Valve
SRVOOS	Safety Relief Valve Out-of-Service
SS	Steady-State
STP	Simulated Thermal Power
TBV	Turbine Bypass Valve
TBVINS	Turbine Bypass Valves In Service
TBVOOS	Turbine Bypass Valves Out-of-Service (all bypass valves OOS)
TIP	Traversing Incore Probe
TLO	Two Loop Operation
TS	Technical Specification
TSSS	Technical Specification SCRAM Speed

CAUTION
References to COLR Figures or Tables should be made using titles only; Figure and Table numbers may change from cycle to cycle.

Introduction and Summary

The Brunswick Unit 2, Cycle 25 COLR provides values for the core operation limits and setpoints required by Technical Specifications (TS) 5.6.5.a.

Required Core Operating Limit (TS 5.6.5.a)	NRC Approved Methodology (TS 5.6.5.b)	Related TS Items
1. The Average Planar Linear Heat Generation Rate (APLHGR) for TS 3.2.1.	1, 2, 6, 7,16, 17, 26	– TS 3.2.1 Limiting Condition for Operation (LCO) (APLHGR) – TS 3.4.1 LCO (Recirculation loops operating) – TS 3.7.6 LCO (Main Turbine Bypass out-of-service)
2. The Minimum Critical Power Ratio (MCPR) and $MCPR_{99.9\%}$ for TS 3.2.2.	1, 6, 7, 8, 9, 11, 12, 13, 19, 21, 22, 25	– TS 3.2.2 LCO (MCPR) – TS 3.4.1 LCO (Recirculation loops operating) – TS 3.7.6 LCO (Turbine bypass out-of-service)
3. The Linear Heat Generation Rate (LHGR) for TS 3.2.3.	3, 5, 6, 7, 8, 9, 12, 13, 20, 23, 24	– TS 3.2.3 LCO (LHGR) – TS 3.4.1 LCO (Recirculation loops operating) – TS 3.7.6 LCO (Turbine bypass out-of-service)
4. The Manual Backup Stability Protection (BSP) Scram Region (Region I), Manual BSP Controlled Entry Region (Region II), the modified Average Power Range Monitor (APRM) Simulated Thermal Power – High Scram setpoints used in the Automated BSP Scram Region, the BSP Boundary for TS 3.3.1.1.	18, 19, 22	– TS Table 3.3.1.1-1, Function 2.f (OPRM Upscale) – TS 3.3.1.1, Condition I and J (Alternate instability detection)
5. The Allowable Values and power range setpoints for Rod Block Monitor (RBM) Upscale Functions for TS 3.3.2.1.	6, 8	– TS Table 3.3.2.1-1, Function 1 (RBM upscale and operability requirements)
The required core operating limits and setpoints listed in TS 5.6.5.a are presented in the COLR, have been determined using Nuclear Regulatory Commission (NRC) approved methodologies (COLR References 1 through 26) in accordance with TS 5.6.5.b, have considered all fuel types utilized in B2C25, and are established such that all applicable limits of the plant safety analysis are met in accordance with TS 5.6.5.c.		

In addition to the TS required core operating limits and setpoints, this COLR also includes maps showing the allowable power/flow operating ranges including the stability ranges.
The generation of this COLR is documented in Reference 34 and is based on analysis results documented in References 31,32, and 33.

APLHGR Limits

Steady-state $MAPLHGR_{SS}$ limits are provided for Framatome Fuel (Table 23). These steady-state $MAPLHGR_{SS}$ limits must be modified as follows:

- Framatome Fuel MAPLHGR limits do not have a power, flow, or EOOS dependency.
- The applied MAPLHGR limit is dependent on the number of recirculation loops in operation. The steady-state MAPLHGR limit must be modified by a $MAPFAC_{SLO}$ multiplier when in SLO. $MAPFAC_{SLO}$ has a fuel design dependency as shown below.

The applied TLO and SLO MAPLHGR limits are determined as follows:

$$\text{MAPLHGR Limit}_{TLO} = MAPLHGR_{SS}$$

$$\text{MAPLHGR Limit}_{SLO} = MAPLHGR_{SS} \times MAPFAC_{SLO}$$

where $MAPFAC_{SLO}$ = 0.80 for ATRIUM 10XM and
where $MAPFAC_{SLO}$ = 0.85 for ATRIUM 11 fuel

Linear interpolation should be used to determine intermediate values between the values listed in the table.

MCPR Limits

The MCPR limits presented in Tables 5 through 14 are based on the TLO and SLO $MCPR_{99.9\%}$ values of 1.08 and 1.09, respectively, which meet the requirement of Technical Specification 2.1.1.2.

- MCPR limits have a core power and core flow dependency. Power-dependent $MCPR_p$ limits are presented in Tables 5 through 13 while flow-dependent $MCPR_f$ limits are presented in Table 14.
- Power-dependent $MCPR_P$ limits are dependent on CAVEX, SCRAM insertion speed, EOOS, fuel design, number of operating recirculation loops (i.e., TLO or SLO), core flow and core thermal power. Values for the CAVEX breakpoints are provided in Table 4. See COLR section titled "Equipment Out-of-Service" for a list of analyzed EOOS conditions. Care should be used when selecting the appropriate limits set.
- The MCPR limits are established such that they bound all pressurization and non-pressurization events.
- The power-dependent $MCPR_p$ limits (Tables 5-13) must be adjusted by an adder of +0.01 when in SLO.

The applied TLO and SLO MCPR limits are determined as follows:

$$\text{MCPR Limit}_{TLO} = (MCPR_p, MCPR_f)_{max}$$

$$\text{MCPR Limit}_{SLO} = (MCPR_p + 0.01, MCPR_f)_{max}$$

Linear interpolation should be used to determine intermediate values between the values listed in the tables. Some of the limits tables show step changes at 26.0%P and 50.0%P. **IF** performing a hand calculation of a limit **AND** the power is exactly on the breakpoint (i.e. 26.0 or 50.0), **THEN** select the most restrictive limit associated with the breakpoint.

LHGR Limits

Steady-state $LHGR_{SS}$ limits are provided for Framatome Fuel (Table 15). These steady-state $LHGR_{SS}$ limits must be modified as follows:

- Framatome Fuel LHGR limits have a core power and core flow dependency. Framatome Fuel power-dependent $LHGRFAC_p$ multipliers (Tables 16-21) and flow-dependent $LHGRFAC_f$ multipliers (Table 22) must be used to modify the steady-state $LHGR_{SS}$ limits (Table 15) for off-rated conditions.
- Framatome Fuel power-dependent $LHGRFAC_p$ multipliers are dependent on CAVEX, SCRAM insertion speed, EOOS, fuel design, core flow and core thermal power. Values for the CAVEX breakpoints are provided in Table 4. See COLR section titled "Equipment Out-of-Service" for a list of analyzed EOOS conditions. Care should be used when selecting the appropriate multiplier set.
- The applied LHGR limit is not dependent on the number of operating recirculation loops. No adjustment to the LHGR limit is necessary for SLO.

The applied LHGR limit is determined as follows:

$$\text{LHGR Limit} = LHGR_{SS} \times (LHGRFAC_p, LHGRFAC_f)_{min}$$

Linear interpolation should be used to determine intermediate values between the values listed in the tables. Some of the limits tables show step changes at 26.0%P and 50.0%P. **IF** performing a hand calculation of a limit **AND** the power is exactly on the breakpoint (i.e. 26.0 or 50.0), **THEN** select the most restrictive limit associated with the breakpoint.

The cycle-specific off-rated flow dependent LHGR set-down bounds those assumed in the MELLLA+ plant-specific ECCS-LOCA analyses.

CDA Setpoints

Brunswick has implemented the Best-estimate Enhanced Option-III (BEO-III) with the Confirmation Density Algorithm (CDA) stability solution using the Oscillation Power Range Monitor (OPRM) as described in References 19 and 22. The Detect and Suppress function of the BEO-III w/ CDA solution based on the OPRM system relies on the CDA, which constitutes the licensing basis. The Backup Stability Protection (BSP) solution described in Reference 22 may be used by the plant in the event the OPRM Upscale function is declared inoperable.

The safety evaluation (Reference 30) concluded that the BEO-III w/ CDA solution is acceptable subject to certain cycle-specific limitations and conditions (Reference 35). As described in Reference 33, these limitations and conditions are met for B2C25.

A reload BEO-III w/ CDA evaluation has been performed in accordance with References 19 and 22. The MCPR limits presented in Tables 5 through 14 bound the minimum stability MCPR values determined for B2C25 in the reload evaluation.

The S_{AD} setpoint value of 1.10 is applicable to TLO and SLO.

Reference 22 describes two BSP options that are based on selected elements from three distinct constituents: BSP Manual Regions, BSP Boundary, and Automated BSP (ABSP) setpoints.

Reference 22 defines the BSP boundary as the MELLLA boundary. The Manual BSP region boundaries were validated for Brunswick Unit 2 Cycle 25 for nominal feedwater temperature operation and reduced feedwater temperature. The endpoints of the regions are defined in Table 3.1 and Table 3.2. The Manual BSP region boundary endpoints are calculated with the Reference 18 methodology and connected using the Generic Shape Function (GSF), which is described in Reference 29.

The ABSP Average Power Range Monitor (APRM) Simulated Thermal Power (STP) setpoints associated with the ABSP Scram Region are determined for Cycle 25 and are defined in Table 3.3. These ABSP setpoints are applicable to both TLO and SLO as well as nominal and reduced feedwater temperature operation.

The Manual Backup Stability Protection (BSP) Regions I and II are documented on the Power/Flow maps as is the modified APRM Simulated Thermal Power (STP) high SCRAM setpoints and the BSP Boundary.

The power/flow maps (Figures 1-6) were validated for B2C25 based on Reference 33 using the Reference 22 methodology to facilitate operation under BEO-III w/ CDA as implemented by Function 2.f of Table 3.3.1.1-1 and LCO Conditions I and J of Technical Specification 3.3.1.1. The generation of these maps is documented in Reference 32. All maps illustrate the region of the power/flow map above 23% RTP and below 75% drive flow (correlated to core flow) where the OPRM system is required to be enabled. Figures 1-6 were included in the COLR as an operator aid and not a licensing requirement. Figures 5 and 6 are the power/flow maps for use in FWTR.

The maps supporting an operable OPRM (Figures 1, 3 and 5) show a Scram Avoidance Region, which is not a licensing requirement but is an operator aid to illustrate where there is increased probability the OPRM system may generate a scram to avoid an instability event. Figures 2, 4, and 6 support an inoperable OPRM and highlight the Manual Backup Stability Regions I and II, the modified APRM STP high SCRAM setpoints, and the BSP Boundary. Note that the STP scram and rod block limits are defined in Technical Specifications, the Technical Requirements Manual, and/or Plant procedures, and are included in the COLR as an operator aid rather than a licensing requirement.

Figures 3 and 4 implement the corrective action for AR-217345 which restricts reactor power to no more than 50% RTP when in SLO with OPRM operable or inoperable. This operator aid is intended to mitigate a spurious OPRM trip signal which could result from APRM noise while operating at high power levels.

RBM Setpoints

The nominal trip setpoints and allowable values of the control rod withdrawal block instrumentation are presented in Table 1 and were determined to be consistent with the bases of the ARTS program (Reference 27). These setpoints will ensure the power-dependent MCPR limits will provide adequate protection against violation of the $MCPR_{99.9\%}$ during a postulated CRWE event. Reference 31 revised these setpoints to reflect changes associated with the installation of the NUMAC PRNM system. RBM operability requirements, consistent with Notes (a) through (e) of Technical Specification Table 3.3.2.1-1, are provided in Table 2.

Equipment Out-of-Service

Brunswick Unit 2, Cycle 25 is analyzed for the following operating conditions with applicable MCPR, APLHGR and LHGR limits.

- Base Case Operation
- SLO
- TBVOOS
- FHOOS
- Combined TBVOOS and FHOOS

Base Case Operation as well as the above-listed EOOS conditions assume all the items OOS below. These conditions are general analysis assumptions used to ensure conservative analysis results and were not meant to define specific EOOS conditions beyond those already defined in Technical Specifications.

- Any 1 inoperable SRV
- 2 inoperable TBV (Note that for TBVOOS, TBVOOS/FHOOS, all 10 TBVs are assumed inoperable)
- Up to 40% of the TIP channels OOS
- Up to 50% of the LPRMs OOS

Please note that during FFTR/Coastdown, FHOOS is included in Base Case Operation and TBVOOS.

Single Loop Operation

Brunswick Unit 2, Cycle 25 may operate in SLO up to a maximum core flow of 45 Mlbm/hr which corresponds to a maximum power level of 71.1% RTP with applicable MCPR, APLHGR and LHGR limits. These power and flow limitations also apply when operating with jet pump loop flow mismatch conditions (LCO 3.4.1). The following must be considered when operating in SLO:

- SLO is not permitted with RFWT (FHOOS/FFTR).
- SLO is not permitted with TBVOOS.
- SLO is not permitted with MSIVOOS.
- SLO is not permitted within the MELLLA+ operating domain.

Various indicators on the Power/Flow Maps are provided not as operating limits but rather as a convenience for the operators. The purposes for some of these indicators are as follows:

- The SLO Entry Rod Line is shown on the TLO maps to avoid regions of instability in the event of a pump trip.
- A maximum core flow line is shown on the SLO maps to avoid vibration problems.
- APRM STP Scram and Rod Block nominal trip setpoint limits are shown at the estimated core flow corresponding to the actual drive flow-based setpoints to indicate where the Operator may encounter these setpoints (See LCO 3.3.1.1, Reactor Protection System Instrumentation Function 2.b: Average Power Range Monitors Simulated Thermal Power - High Allowable Value).
- When in SLO, Figures 3 and 4 implement the corrective action for AR-217345 which restricts reactor power to no more than 50% RTP with OPRM operable or inoperable. This operator aid is intended to mitigate a spurious OPRM trip signal which could result from APRM noise while operating at high power levels.
- If OPRMs are inoperable in SLO, the expansion of the ABSP region results in power being restricted to 39% RTP as shown in Figure 4.

Inoperable Main Turbine Bypass System

Brunswick Unit 2, Cycle 25 may operate with an inoperable Main Turbine Bypass System over the entire MEOD range and in the MELLLA+ domain for all cycle exposures with applicable APLHGR, MCPR and LHGR limits as specified in the COLR. An operable Main Turbine Bypass System with only two inoperable bypass valves was assumed in the development of the Base Case Operation limits. Base Case Operation is synonymous with TBVINS. The following must be considered when operating with TBVOOS:

- Three or more inoperable bypass valves renders the entire Main Turbine Bypass System inoperable requiring the use of TBVOOS limits. The TBVOOS analysis supports operation with all bypass valves inoperable.
- Prior to reaching the EOCLB exposure breakpoint, operation with FWTR >10˚F and reactor power ≥ 23% RTP requires use of the combined TBVOOS/FHOOS limits.
- TBVOOS operation coincident with FHOOS is supported using the combined TBVOOS/FHOOS limits.
- SLO is not permitted with TBVOOS.

Feedwater Temperature Reduction

Brunswick Unit 2, Cycle 25 may operate with RFWT over the entire MEOD range and cycle with applicable APLHGR, MCPR and LHGR limits as specified in the COLR. NFWT is defined as the range of feedwater temperatures from NFWT to NFWT - 10˚F. NFWT and its allowable variation were assumed in the development of the Base Case Operation limits. The FHOOS limits and FFTR/Coastdown limits were developed for a maximum feedwater temperature reduction of 110.3˚F. The following must be considered when operating with RFWT:

- Although the acronyms FWTR, FHOOS, RFWT and FFTR all involve reduced feedwater temperature, the use of FFTR is reserved for cycle energy extension using reduced feedwater temperature at and beyond a core average exposure of EOCLB using FFTR/Coastdown limits.
- Prior to reaching the EOCLB exposure breakpoint, operation with FWTR >10˚F and reactor power ≥ 23% RTP requires use of the FHOOS limits.
- Until a core average exposure of EOCLB is reached, implementation of the FFTR/Coastdown limits is not required even if coastdown begins early.
- When operating with RFWT, the appropriate MELLLA+ Power/Flow Maps (Figures 5 and 6) must be used.
- FHOOS operation coincident with TBVOOS is supported using the combined TBVOOS/FHOOS limits.
- SLO is not permitted with RFWT.
- FWTR operation within the MELLLA+ operating domain is not allowed.
- NFWT limits have **not** been conservatively adjusted to eliminate the need to use RFWT limits below 50% RTP.

References

In accordance with Brunswick Unit 2 Technical Specification 5.6.5.b, the analytical methods for determining Brunswick Unit 2 core operating limits have been specifically reviewed and approved by the NRC and are listed as References 1 through 26.

1. NEDE-24011-P-A, "GESTAR II - General Electric Standard Application for Reactor Fuel," and US Supplement, Revision 15, September 2005.
2. XN-NF-81-58(P)(A) and Supplements 1 and 2, “RODEX2 Fuel Rod Thermal-Mechanical Response Evaluation Model,” Revision 2, March 1984.
3. XN-NF-85-67(P)(A), “Generic Mechanical Design for Exxon Nuclear Jet Pump BWR Reload Fuel,” Revision 1, September 1986.
4. EMF-85-74(P) Supplement 1(P)(A) and Supplement 2(P)(A), “RODEX2A (BWR) Fuel Rod Thermal-Mechanical Evaluation Model,” Revision 0, February 1998.
5. ANF-89-98(P)(A), “Generic Mechanical Design Criteria for BWR Fuel Designs,” Revision 1, May 1995.
6. XN-NF-80-19(P)(A) Volume 1 and Volume 1 Supplements 1 and 2, “Exxon Nuclear Methodology for Boiling Water Reactors - Neutronic Methods for Design and Analysis,” March 1983.
7. XN-NF-80-19(P)(A) Volume 4, “Exxon Nuclear Methodology for Boiling Water Reactors: Application of the ENC Methodology to BWR Reloads,” Revision 1, June 1986.
8. EMF-2158(P)(A), “Siemens Power Corporation Methodology for Boiling Water Reactors: Evaluation and Validation of CASMO-4/MICROBURN-B2,” Revision 0, October 1999.
9. XN-NF-80-19(P)(A) Volume 3, “Exxon Nuclear Methodology for Boiling Water Reactors, THERMEX: Thermal Limits Methodology Summary Description,” Revision 2, January 1987.
10. ANP-10333P-A, “AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Control Rod Drop Accident (CRDA)”, Revision 0, March 2018.
11. ANP-10307PA, “AREVA MCPR Safety Limit Methodology for Boiling Water Reactors,” Revision 0, June 2011.
12. ANP-10300P-A, “AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Transient and Accident Scenarios”, Revision 1, January 2018.
13. ANF-1358(P)(A), “The Loss of Feedwater Heating Transient in Boiling Water Reactors,” Revision 3, September 2005.
14. EMF-2209(P)(A), “SPCB Critical Power Correlation,” Revision 3, September 2009.
15. EMF-2245(P)(A), “Application of Siemens Power Corporation's Critical Power Correlations to Co-Resident Fuel,” Revision 0, August 2000.
16. EMF-2361(P)(A), “EXEM BWR-2000 ECCS Evaluation Model,” Revision 0, May 2001.
17. EMF-2292(P)(A), “ATRIUM™-10: Appendix K Spray Heat Transfer Coefficients,” Revision 0, September 2000.
18. EMF-CC-074(P)(A) Volume 4, “BWR Stability Analysis - Assessment of STAIF with Input from MICROBURN-B2,” Revision 0, August 2000.
19. ANP-3703P, “BEO-III Analysis Methodology for Brunswick Using RAMONA5-FA”, Revision 0, August 2018.
20. BAW-10247PA, “Realistic Thermal-Mechanical Fuel Rod Methodology for Boiling Water Reactors,” Revision 0, April 2008.
21. ANP-10298P-A, “ACE/ATRIUM 10XM Critical Power Correlation,” Revision 1, March 2014.

22. DPC-NE-1009-P, “Brunswick Nuclear Plant Implementation of Best-estimate Enhanced Option-III”, Revision 0, September 2018.
23. BAW-10247P-A, Supplement 2P-A, “Realistic Thermal-Mechanical Fuel Rod Methodology for Boiling Water Reactors Supplement 2: Mechanical Methods”, Revision 0, August 2018.
24. ANP-10340P-A, “Incorporation of Chromia-Doped Fuel Properties in AREVA Approved Methods”, Revision 0, May 2018.
25. ANP-10335P-A, “ACE/ATRIUM 11 Critical Power Correlation”, Revision 0, May 2018.
26. ANP-10332P-A, “AURORA-B: An Evaluation Model for Boiling Water Reactors; Application to Loss of Coolant Accident Scenarios”, Revision 0, March 2019.
27. NEDC-31654P, “Maximum Extended Operating Domain Analysis for Brunswick Steam Electric Plant,” February 1989.
28. Not Used.
29. OG02-0119-260, “Backup Stability Protection (BSP) for Inoperable Option III Solution”, July 2002.
30. NRC letter to Duke Energy Progress, LLC, “Brunswick Steam Electric Plant, Units 1 and 2 – Issuance of Amendment Nos. 299 and 327 to Revise Technical Specification 5.6.5b to Allow Application of Advanced Framatome ATRIUM 11 Fuel Methodologies (EPID L-2018-LLA-0273),” dated March 6, 2020 (ADAMS Accession No. ML20073F186).
31. BNP Design Calculation 2C51-0001, “Power Range Neutron Monitoring System Setpoint Uncertainty and Scaling Calculation (2-C51-APRM-1 through 4 Loops and 2-C51 RBM-A and B Loops),” Revision 4, September 2018.
32. BNP Design Calculation 0B21-2045, “BNP Power/Flow Maps for MELLLA+,” Revision 2, January 2020.
33. ANP-3897P, “Brunswick Unit 2 Cycle 25 Reload Safety Analysis,” Revision 0, January 2021.
34. BNP Design Calculation 2B21-2080, “Preparation of the B2C25 Core Operating Limits Report,” Revision 0, March 2021.
35. NRC E-mail Capture, “Request for Additional Information – Brunswick ATRIUM 11 LAR,” (ADAMS Accession Number ML19283C829), October 9, 2019.

Table 1

RBM System Setpoints[1]

Setpoint [a]	Setpoint Value	Allowable Value
Lower Power Setpoint (LPSP[b])	≤ 27.7	≤ 29.0
Intermediate Power Setpoint (IPSP[b])	≤ 62.7	≤ 64.0
High Power Setpoint (HPSP[b])	≤ 82.7	≤ 84.0
Low Trip Setpoint (LTSP[c,d])	≤ 120.1	≤ 120.6
Intermediate Trip Setpoint (ITSP[c,d])	≤ 115.1	≤ 115.6
High Trip Setpoint (HTSP[c,d])	≤ 110.3	≤ 110.8
RBM Time Delay (t_{d2})	0 seconds	< 2.0 seconds

a See Table 2 for RBM Operability Requirements.

b Setpoints in percent of Rated Thermal Power.

c Setpoints relative to a full scale reading of 125. For example, ≤ 120.1 means ≤ 120.1/125.0 of full scale.

d Trip setpoints and allowable values are based on a HTSP Analytical Limit of 113.2 with RBM filter.

1 This table is referred to by Technical Specification 3.3.2.1 (Table 3.3.2.1-1) and 5.6.5.a.5.

Table 2

RBM Operability Requirements[2]

IF the following conditions are met, **THEN**
RBM Not Required Operable

Thermal Power (% rated)	MCPR
≥ 29% and < 90%	≥ 1.71 TLO ≥ 1.74 SLO
≥ 90%	≥ 1.41 TLO

2 Requirements valid for all fuel designs, all SCRAM insertion times and all core average exposure ranges.

Table 3.1

BSP Endpoints for Nominal Feedwater Temperature[3,4]

Endpoint	Power (%)	Flow (%)	Definition
A1	57.0	40.6	Scram Region Boundary, HFCL
B1	42.0	31.7	Scram Region Boundary, NCL
A2	64.5	50.0	Controlled Entry Region Boundary, HFCL
B2	28.9	31.9	Controlled Entry Region Boundary, NCL

Table 3.2

BSP Endpoints for Reduced Feedwater Temperature[3,4]

Endpoint	Power (%)	Flow (%)	Definition
A1	65.9	51.8	Scram Region Boundary, HFCL
B1	36.5	31.9	Scram Region Boundary, NCL
A2	69.8	56.8	Controlled Entry Region Boundary, HFCL
B2	28.9	31.9	Controlled Entry Region Boundary, NCL

Table 3.3

ABSP Setpoints for the Scram Region[3,5]

Parameter	Symbol	Value
Slope of ABSP APRM flow-biased trip linear segment.	m_{TRIP}	2.00 %RTP/%RDF
ABSP APRM flow-biased trip setpoint power intercept. Constant Power Line for Trip from zero Drive Flow to Flow Breakpoint value.	$P_{BSP-TRIP}$	42.0 %RTP
ABSP APRM flow-biased trip setpoint drive flow intercept. Constant Flow Line for Trip.	$W_{BSP-TRIP}$	≥37.5 %RDF
Flow Breakpoint value	$W_{BSP-BREAK}$	25.0 %RDF

3 These tables are referred to by Technical Specification 3.3.1.1 (Table 3.3.1.1-1) and 5.6.5.a.4.

4 The BSP Boundary for Nominal and Reduced Feedwater Temperature is defined by the MELLLA boundary line and extends from the natural circulation boundary to rated power.

5 When in SLO the ABSP STP Scram is modified by the applied SLO ΔW as shown in Figure 4.

Table 4

Exposure Basis[6] for Brunswick Unit 2 Cycle 25 Transient Analysis

Core Average Exposure (MWd/MTU)	Comments
34,021	Breakpoint for exposure dependent $MCPR_p$ limits (NEOC)
36,653	Design basis rod patterns to EOFP + 15 EFPD (EOCLB)
38,689	End of cycle with FFTR/Coastdown - Maximum Core Exposure (MCE)

6 The exposure basis for the defined break points is the core average exposure (CAVEX) values shown above regardless of the actual BOC CAVEX value of the As-Loaded Core.

Table 5

Power-Dependent $MCPR_p$ Limits[7]

NSS Insertion Times
BOC to < NEOC

EOOS Condition	Power (% rated)	ATRIUM 10XM $MCPR_p$		ATRIUM 11 $MCPR_p$	
Base case operation	100.0	1.38		1.33	
	80.0	1.48		1.38	
	50.0	1.65		1.52	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.69	1.84	1.66
	26.0	2.20	2.01	2.18	1.90
	26.0	2.21	2.06	2.20	1.99
	23.0	2.22	2.08	2.23	1.99
TBVOOS	100.0	1.38		1.36	
	80.0	1.48		1.41	
	50.0	1.65		1.61	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.69	1.84	1.66
	26.0	2.20	2.01	2.18	1.90
	26.0	2.74	2.72	2.80	2.55
	23.0	2.91	2.81	2.92	2.69
FHOOS	100.0	1.38		1.33	
	80.0	1.48		1.38	
	50.0	1.65		1.52	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.73	1.84	1.66
	26.0	2.20	2.01	2.18	1.91
	26.0	2.21	2.08	2.20	1.99
	23.0	2.23	2.19	2.23	2.05
TBVOOS FHOOS	100.0	1.38		1.36	
	80.0	1.48		1.44	
	50.0	1.65		1.67	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.73	1.84	1.66
	26.0	2.20	2.01	2.18	1.91
	26.0	2.89	2.77	2.97	2.55
	23.0	3.06	2.84	3.05	2.72

7 Limits support operation with any combination of any 1 inoperable SRV, 2 inoperable TBV, up to 40% of the TIP channels out-of-service, and up to 50% of the LPRMs out-of-service. For single-loop operation, the TLO MCPRp limits shown above must be adjusted by adding 0.01. SLO not permitted for FHOOS, TBVOOS or MSIVOOS. FHOOS not permitted in the MELLLA+ domain.

Table 6

Power-Dependent $MCPR_p$ Limits[8]

ESS Insertion Times
BOC to < NEOC

EOOS Condition	Power (% rated)	ATRIUM 10XM $MCPR_p$		ATRIUM 11 $MCPR_p$	
Base case operation	100.0	1.38		1.33	
	80.0	1.48		1.38	
	50.0	1.65		1.52	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.69	1.84	1.66
	26.0	2.20	2.01	2.18	1.90
	26.0	2.21	2.06	2.20	1.99
	23.0	2.22	2.08	2.23	1.99
TBVOOS	100.0	1.38		1.37	
	80.0	1.48		1.41	
	50.0	1.65		1.61	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.69	1.84	1.66
	26.0	2.20	2.01	2.18	1.90
	26.0	2.74	2.72	2.80	2.55
	23.0	2.91	2.81	2.92	2.69
FHOOS	100.0	1.38		1.33	
	80.0	1.48		1.38	
	50.0	1.65		1.52	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.73	1.84	1.66
	26.0	2.20	2.01	2.18	1.91
	26.0	2.21	2.08	2.20	1.99
	23.0	2.23	2.19	2.23	2.05
TBVOOS FHOOS	100.0	1.38		1.37	
	80.0	1.48		1.44	
	50.0	1.65		1.67	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.73	1.84	1.66
	26.0	2.20	2.01	2.18	1.91
	26.0	2.89	2.77	2.97	2.55
	23.0	3.06	2.84	3.05	2.72

8 Limits support operation with any combination of any 1 inoperable SRV, 2 inoperable TBV, up to 40% of the TIP channels out-of-service, and up to 50% of the LPRMs out-of-service. For single-loop operation, the TLO MCPRp limits shown above must be adjusted by adding 0.01. SLO not permitted for FHOOS, TBVOOS or MSIVOOS. FHOOS not permitted in the MELLLA+ domain.

Table 7

Power-Dependent $MCPR_p$ Limits[9]

TSSS Insertion Times
BOC to < NEOC

EOOS Condition	Power (% rated)	ATRIUM 10XM $MCPR_p$		ATRIUM 11 $MCPR_p$	
Base case operation	100.0	1.38		1.36	
	80.0	1.48		1.39	
	50.0	1.65		1.60	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.69	1.84	1.66
	26.0	2.20	2.01	2.18	1.90
	26.0	2.21	2.06	2.20	1.99
	23.0	2.22	2.08	2.23	1.99
TBVOOS	100.0	1.40		1.39	
	80.0	1.48		1.45	
	50.0	1.65		1.67	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.69	1.84	1.66
	26.0	2.20	2.01	2.18	1.90
	26.0	2.74	2.72	2.80	2.55
	23.0	2.91	2.81	2.92	2.69
FHOOS	100.0	1.38		1.36	
	80.0	1.48		1.39	
	50.0	1.65		1.60	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.73	1.84	1.66
	26.0	2.20	2.01	2.18	1.91
	26.0	2.21	2.08	2.20	1.99
	23.0	2.23	2.19	2.23	2.05
TBVOOS FHOOS	100.0	1.40		1.39	
	80.0	1.48		1.47	
	50.0	1.65		1.70	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.73	1.84	1.66
	26.0	2.20	2.01	2.18	1.91
	26.0	2.89	2.77	2.97	2.55
	23.0	3.06	2.84	3.05	2.72

9 Limits support operation with any combination of any 1 inoperable SRV, 2 inoperable TBV, up to 40% of the TIP channels out-of-service, and up to 50% of the LPRMs out-of-service. For single-loop operation, the TLO MCPRp limits shown above must be adjusted by adding 0.01. SLO not permitted for FHOOS, TBVOOS or MSIVOOS. FHOOS not permitted in the MELLLA+ domain.

Table 8

Power-Dependent $MCPR_p$ Limits[10]

NSS Insertion Times
BOC to < EOCLB

EOOS Condition	Power (% rated)	ATRIUM 10XM $MCPR_p$		ATRIUM 11 $MCPR_p$	
Base case operation	100.0	1.38		1.36	
	80.0	1.48		1.39	
	50.0	1.65		1.52	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.69	1.84	1.66
	26.0	2.20	2.01	2.18	1.90
	26.0	2.21	2.06	2.20	1.99
	23.0	2.22	2.08	2.23	1.99
TBVOOS	100.0	1.40		1.39	
	80.0	1.48		1.45	
	50.0	1.65		1.62	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.69	1.84	1.66
	26.0	2.20	2.01	2.18	1.90
	26.0	2.74	2.72	2.80	2.55
	23.0	2.91	2.81	2.92	2.69
FHOOS	100.0	1.38		1.36	
	80.0	1.48		1.39	
	50.0	1.65		1.52	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.73	1.84	1.66
	26.0	2.20	2.01	2.18	1.91
	26.0	2.21	2.08	2.20	1.99
	23.0	2.23	2.19	2.23	2.05
TBVOOS FHOOS	100.0	1.41		1.41	
	80.0	1.48		1.46	
	50.0	1.65		1.67	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.73	1.84	1.66
	26.0	2.20	2.01	2.18	1.91
	26.0	2.89	2.77	2.97	2.55
	23.0	3.06	2.84	3.05	2.72

10 Limits support operation with any combination of any 1 inoperable SRV, 2 inoperable TBV, up to 40% of the TIP channels out-of-service, and up to 50% of the LPRMs out-of-service. For single-loop operation, the TLO MCPRp limits shown above must be adjusted by adding 0.01. SLO not permitted for FHOOS, TBVOOS or MSIVOOS. FHOOS not permitted in the MELLLA+ domain.

Table 9

Power-Dependent $MCPR_p$ Limits[11]

ESS Insertion Times
BOC to < EOCLB

EOOS Condition	Power (% rated)	ATRIUM 10XM $MCPR_p$		ATRIUM 11 $MCPR_p$	
Base case operation	100.0	1.38		1.36	
	80.0	1.48		1.39	
	50.0	1.65		1.52	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.69	1.84	1.66
	26.0	2.20	2.01	2.18	1.90
	26.0	2.21	2.06	2.20	1.99
	23.0	2.22	2.08	2.23	1.99
TBVOOS	100.0	1.41		1.40	
	80.0	1.48		1.45	
	50.0	1.65		1.62	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.69	1.84	1.66
	26.0	2.20	2.01	2.18	1.90
	26.0	2.74	2.72	2.80	2.55
	23.0	2.91	2.81	2.92	2.69
FHOOS†	100.0	1.38		1.36	
	80.0	1.48		1.39	
	50.0	1.65		1.52	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.73	1.84	1.66
	26.0	2.20	2.01	2.18	1.91
	26.0	2.21	2.08	2.20	1.99
	23.0	2.23	2.19	2.23	2.05
TBVOOS FHOOS†	100.0	1.41		1.41	
	80.0	1.48		1.46	
	50.0	1.65		1.67	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.73	1.84	1.66
	26.0	2.20	2.01	2.18	1.91
	26.0	2.89	2.77	2.97	2.55
	23.0	3.06	2.84	3.05	2.72

[11] Limits support operation with any combination of any 1 inoperable SRV, 2 inoperable TBV, up to 40% of the TIP channels out-of-service, and up to 50% of the LPRMs out-of-service. For single-loop operation, the TLO MCPRp limits shown above must be adjusted by adding 0.01. SLO not permitted for FHOOS, TBVOOS or MSIVOOS. FHOOS not permitted in the MELLLA+ domain.

Table 10

Power-Dependent $MCPR_p$ Limits[12]

TSSS Insertion Times
BOC to < EOCLB

EOOS Condition	Power (% rated)	ATRIUM 10XM $MCPR_p$		ATRIUM 11 $MCPR_p$	
Base case operation	100.0	1.42		1.44	
	80.0	1.48		1.44	
	50.0	1.65		1.61	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.69	1.85	1.67
	26.0	2.20	2.01	2.19	1.91
	26.0	2.21	2.06	2.21	2.00
	23.0	2.22	2.08	2.24	2.00
TBVOOS	100.0	1.48		1.50	
	80.0	1.51		1.51	
	50.0	1.68		1.71	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.91	1.72	1.88	1.70
	26.0	2.23	2.04	2.22	1.94
	26.0	2.77	2.75	2.84	2.59
	23.0	2.94	2.84	2.96	2.73
FHOOS†	100.0	1.42		1.44	
	80.0	1.48		1.44	
	50.0	1.65		1.61	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.73	1.85	1.67
	26.0	2.20	2.01	2.19	1.92
	26.0	2.21	2.08	2.21	2.00
	23.0	2.23	2.19	2.24	2.06
TBVOOS FHOOS†	100.0	1.48		1.50	
	80.0	1.51		1.51	
	50.0	1.68		1.74	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.91	1.76	1.88	1.70
	26.0	2.23	2.04	2.22	1.95
	26.0	2.92	2.80	3.01	2.59
	23.0	3.09	2.87	3.09	2.76

12 Limits support operation with any combination of any 1 inoperable SRV, 2 inoperable TBV, up to 40% of the TIP channels out-of-service, and up to 50% of the LPRMs out-of-service. For single-loop operation, the TLO MCPRp limits shown above must be adjusted by adding 0.01. SLO not permitted for FHOOS, TBVOOS or MSIVOOS. FHOOS not permitted in the MELLLA+ domain.

Table 11

Power-Dependent $MCPR_p$ Limits[13]

NSS Insertion Times
BOC to < MCE (FFTR/Coastdown)

EOOS Condition	Power (% rated)	ATRIUM 10XM $MCPR_p$		ATRIUM 11 $MCPR_p$	
Base case Operation	100.0	1.38		1.36	
	80.0	1.48		1.39	
	50.0	1.65		1.52	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
(FFTR/FHOOS Included)	50.0	1.88	1.73	1.84	1.66
	26.0	2.20	2.01	2.18	1.91
	26.0	2.21	2.08	2.20	1.99
(Bounds operation with NFWT)	23.0	2.23	2.19	2.23	2.05
TBVOOS	100.0	1.42		1.41	
	80.0	1.48		1.46	
	50.0	1.65		1.67	
(FFTR/FHOOS Included)		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.73	1.84	1.66
	26.0	2.20	2.01	2.18	1.91
(Bounds operation with NFWT)	26.0	2.89	2.77	2.97	2.55
	23.0	3.06	2.84	3.05	2.72

13 Limits support operation with any combination of any 1 inoperable SRV, 2 inoperable TBV, up to 40% of the TIP channels out-of-service, and up to 50% of the LPRMs out-of-service. For single-loop operation, the TLO MCPRp limits shown above must be adjusted by adding 0.01. SLO not permitted for FHOOS, TBVOOS or MSIVOOS. FHOOS not permitted in the MELLLA+ domain.

Table 12

Power-Dependent $MCPR_p$ Limits[14]

ESS Insertion Times
BOC to < MCE (FFTR/Coastdown)

EOOS Condition	Power (% rated)	ATRIUM 10XM $MCPR_p$		ATRIUM 11 $MCPR_p$	
	100.0	1.38		1.36	
Base case Operation	80.0	1.48		1.39	
	50.0	1.65		1.52	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
(FFTR/FHOOS Included)	50.0	1.88	1.73	1.84	1.66
	26.0	2.20	2.01	2.18	1.91
	26.0	2.21	2.08	2.20	1.99
(Bounds operation with NFWT)	23.0	2.23	2.19	2.23	2.05
	100.0	1.42		1.41	
TBVOOS	80.0	1.48		1.46	
	50.0	1.65		1.67	
(FFTR/FHOOS Included)		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.73	1.84	1.66
	26.0	2.20	2.01	2.18	1.91
(Bounds operation with NFWT)	26.0	2.89	2.77	2.97	2.55
	23.0	3.06	2.84	3.05	2.72

14 Limits support operation with any combination of any 1 inoperable SRV, 2 inoperable TBV, up to 40% of the TIP channels out-of-service, and up to 50% of the LPRMs out-of-service. For single-loop operation, the TLO MCPRp limits shown above must be adjusted by adding 0.01. SLO not permitted for FHOOS, TBVOOS or MSIVOOS. FHOOS not permitted in the MELLLA+ domain.

Table 13

Power-Dependent $MCPR_p$ Limits[15]

TSSS Insertion Times
BOC to < MCE (FFTR/Coastdown)

EOOS Condition	Power (% rated)	ATRIUM 10XM $MCPR_p$		ATRIUM 11 $MCPR_p$	
Base case Operation	100.0	1.46		1.46	
	80.0	1.50		1.46	
	50.0	1.67		1.62	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
(FFTR/FHOOS Included)	50.0	1.90	1.75	1.86	1.68
	26.0	2.22	2.03	2.20	1.93
	26.0	2.23	2.10	2.22	2.01
(Bounds operation with NFWT)	23.0	2.25	2.21	2.25	2.07
TBVOOS	100.0	1.52		1.52	
	80.0	1.53		1.53	
	50.0	1.70		1.75	
(FFTR/FHOOS Included)		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.93	1.78	1.89	1.71
	26.0	2.25	2.06	2.23	1.96
(Bounds operation with NFWT)	26.0	2.94	2.82	3.02	2.60
	23.0	3.11	2.89	3.10	2.77

15 Limits support operation with any combination of any 1 inoperable SRV, 2 inoperable TBV, up to 40% of the TIP channels out-of-service, and up to 50% of the LPRMs out-of-service. For single-loop operation, the TLO MCPRp limits shown above must be adjusted by adding 0.01. SLO not permitted for FHOOS, TBVOOS or MSIVOOS. FHOOS not permitted in the MELLLA+ domain.

Table 14

Flow-Dependent $MCPR_f$ Limits[16],[17]

Core Flow (% of rated)	ATRIUM 10XM $MCPR_f$	ATRIUM 11 $MCPR_f$
0.0	1.65	1.52
31.0	1.65	1.52
60.0	1.50	--
77.0	--	1.31
81.0	1.31	1.31
100.0	1.31	1.31
107.0	1.31	1.31

16 Limits valid for all SCRAM insertion times, all core average exposure ranges, all EOOS scenarios, and both TLO & SLO.

17 "--" indicates that the fuel limit has no breakpoint at this core flow.

Table 15

Framatome Fuel Steady-State $LHGR_{SS}$ Limits[18]

Peak Pellet Exposure (GWd/MTU)	ATRIUM 10XM LHGR (kW/ft)	ATRIUM 11 LHGR (kW/ft)
0.0	14.1	13.6
6.0	14.1	--
18.9	14.1	--
21.0	--	13.6
53.0	--	10.2
54.0	10.6	--
74.4	5.4	--
80.0	N/A	3.5

[18] "--" indicates that the fuel limit has no breakpoint at this exposure.

Table 16

Framatome Fuel Power-Dependent $LHGRFAC_p$ Multipliers[19]

NSS Insertion Times
BOC to < EOCLB

EOOS Condition	Power (% rated)	ATRIUM 10XM $LHGRFAC_p$		ATRIUM 11 $LHGRFAC_p$	
Base case operation	100.0	1.00		1.00	
	90.0	1.00		1.00	
	50.0	1.00		1.00	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	0.93	1.00	0.86	0.95
	26.0	0.75	0.86	0.68	0.80
	26.0	0.75	0.84	0.68	0.80
	23.0	0.71	0.83	0.64	0.78
TBVOOS	100.0	1.00		1.00	
	90.0	1.00		1.00	
	50.0	0.98		0.97	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	0.93	1.00	0.86	0.95
	26.0	0.75	0.86	0.68	0.80
	26.0	0.45	0.56	0.41	0.51
	23.0	0.41	0.50	0.38	0.46
FHOOS	100.0	1.00		1.00	
	90.0	1.00		1.00	
	50.0	1.00		0.96	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	0.93	1.00	0.86	0.95
	26.0	0.75	0.86	0.68	0.80
	26.0	0.65	0.78	0.61	0.75
	23.0	0.63	0.77	0.59	0.71
TBVOOS FHOOS	100.0	1.00		1.00	
	90.0	1.00		1.00	
	50.0	0.97		0.90	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	0.92	1.00	0.86	0.95
	26.0	0.75	0.86	0.68	0.80
	26.0	0.42	0.52	0.38	0.48
	23.0	0.38	0.47	0.35	0.43

19 Limits support operation with any combination of any 1 inoperable SRV, 2 inoperable TBV, up to 40% of the TIP channels out-of-service, and up to 50% of the LPRMs out-of-service. FHOOS not permitted in the MELLLA+ domain.

Table 17

Framatome Fuel Power-Dependent $LHGRFAC_p$ Multipliers[20]

ESS Insertion Times
BOC to < EOCLB

EOOS Condition	Power (% rated)	ATRIUM 10XM $LHGRFAC_p$		ATRIUM 11 $LHGRFAC_p$	
Base case operation	100.0	1.00		1.00	
	90.0	1.00		1.00	
	50.0	1.00		1.00	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	0.93	1.00	0.86	0.95
	26.0	0.75	0.86	0.68	0.80
	26.0	0.75	0.84	0.68	0.80
	23.0	0.71	0.83	0.64	0.78
TBVOOS	100.0	1.00		1.00	
	90.0	1.00		1.00	
	50.0	0.98		0.97	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	0.93	1.00	0.86	0.95
	26.0	0.75	0.86	0.68	0.80
	26.0	0.45	0.56	0.41	0.51
	23.0	0.41	0.50	0.38	0.46
FHOOS	100.0	1.00		1.00	
	90.0	1.00		1.00	
	50.0	1.00		0.96	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	0.93	1.00	0.86	0.95
	26.0	0.75	0.86	0.68	0.80
	26.0	0.65	0.78	0.61	0.75
	23.0	0.63	0.77	0.59	0.71
TBVOOS FHOOS	100.0	1.00		1.00	
	90.0	1.00		1.00	
	50.0	0.97		0.90	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	0.92	1.00	0.86	0.95
	26.0	0.75	0.86	0.68	0.80
	26.0	0.42	0.52	0.38	0.48
	23.0	0.38	0.47	0.35	0.43

20 Limits support operation with any combination of any 1 inoperable SRV, 2 inoperable TBV, up to 40% of the TIP channels out-of-service, and up to 50% of the LPRMs out-of-service. FHOOS not permitted in the MELLLA+ domain.

Table 18

Framatome Fuel Power-Dependent $LHGRFAC_p$ Multipliers[21, 22]

TSSS Insertion Times
BOC to < EOCLB

EOOS Condition	Power (% rated)	ATRIUM 10XM $LHGRFAC_p$		ATRIUM 11 $LHGRFAC_p$	
Base case operation	100.0	1.00		1.00	
	90.0	1.00		--	
	50.0	1.00		1.00	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	0.93	1.00	0.86	0.95
	26.0	0.75	0.86	0.68	0.80
	26.0	0.75	0.84	0.68	0.80
	23.0	0.71	0.83	0.64	0.78
TBVOOS	100.0	1.00		1.00	
	90.0	1.00		--	
	50.0	0.98		0.92	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	0.93	1.00	0.86	0.95
	26.0	0.75	0.86	0.68	0.80
	26.0	0.45	0.56	0.41	0.51
	23.0	0.41	0.50	0.38	0.46
FHOOS	100.0	1.00		1.00	
	90.0	1.00		--	
	50.0	1.00		0.95	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	0.93	1.00	0.86	0.95
	26.0	0.75	0.86	0.68	0.80
	26.0	0.65	0.78	0.61	0.75
	23.0	0.63	0.77	0.59	0.71
TBVOOS FHOOS	100.0	1.00		0.97	
	90.0	1.00		--	
	50.0	0.92		0.87	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	0.92	1.00	0.86	0.95
	26.0	0.75	0.86	0.68	0.80
	26.0	0.42	0.52	0.38	0.48
	23.0	0.38	0.47	0.35	0.43

21 Limits support operation with any combination of any 1 inoperable SRV, 2 inoperable TBV, up to 40% of the TIP channels out-of-service, and up to 50% of the LPRMs out-of-service. FHOOS not permitted in the MELLLA+ domain.

22 "--" indicates that the fuel limit has no breakpoint at this power.

Table 19

Framatome Fuel Power-Dependent $LHGRFAC_p$ Multipliers[23]

NSS Insertion Times
BOC to < MCE (FFTR/Coastdown)

EOOS Condition	Power (% rated)	ATRIUM 10XM $LHGRFAC_p$		ATRIUM 11 $LHGRFAC_p$	
Base case operation	100.0	1.00		1.00	
	90.0	1.00		1.00	
	50.0	1.00		0.96	
(FFTR/FHOOS included)		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	0.93	1.00	0.86	0.95
	26.0	0.75	0.86	0.68	0.80
(Bounds operation with NFWT)	26.0	0.65	0.78	0.61	0.75
	23.0	0.63	0.77	0.59	0.71
TBVOOS	100.0	1.00		1.00	
	90.0	1.00		1.00	
	50.0	0.97		0.90	
(FFTR/FHOOS included)		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	0.92	1.00	0.86	0.95
(Bounds operation with NFWT)	26.0	0.75	0.86	0.68	0.80
	26.0	0.42	0.52	0.38	0.48
	23.0	0.38	0.47	0.35	0.43

23 Limits support operation with any combination of any 1 inoperable SRV, 2 inoperable TBV, up to 40% of the TIP channels out-of-service, and up to 50% of the LPRMs out-of-service. FHOOS not permitted in the MELLLA+ domain.

Table 20

Framatome Fuel Power-Dependent $LHGRFAC_p$ Multipliers[24]

ESS Insertion Times
BOC to < MCE (FFTR/Coastdown)

EOOS Condition	Power (% rated)	ATRIUM 10XM $LHGRFAC_p$		ATRIUM 11 $LHGRFAC_p$	
Base case operation (FFTR/FHOOS included) (Bounds operation with NFWT)	100.0	1.00		1.00	
	90.0	1.00		1.00	
	50.0	1.00		0.96	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	0.93	1.00	0.86	0.95
	26.0	0.75	0.86	0.68	0.80
	26.0	0.65	0.78	0.61	0.75
	23.0	0.63	0.77	0.59	0.71
TBVOOS (FFTR/FHOOS included) (Bounds operation with NFWT)	100.0	1.00		1.00	
	90.0	1.00		1.00	
	50.0	0.97		0.90	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	0.92	1.00	0.86	0.95
	26.0	0.75	0.86	0.68	0.80
	26.0	0.42	0.52	0.38	0.48
	23.0	0.38	0.47	0.35	0.43

24 Limits support operation with any combination of any 1 inoperable SRV, 2 inoperable TBV, up to 40% of the TIP channels out-of-service, and up to 50% of the LPRMs out-of-service. FHOOS not permitted in the MELLLA+ domain.

Table 21

Framatome Fuel Power-Dependent $LHGRFAC_p$ Multipliers[25, 26]

TSSS Insertion Times
BOC to < MCE (FFTR/Coastdown)

EOOS Condition	Power (% rated)	ATRIUM 10XM $LHGRFAC_p$		ATRIUM 11 $LHGRFAC_p$	
Base case operation	100.0	1.00		1.00	
	90.0	1.00		--	
	50.0	1.00		0.95	
(FFTR/FHOOS included)		> 65%F	≤ 65%F	> 65%F	≤ 65%F
(Bounds operation with NFWT)	50.0	0.93	1.00	0.86	0.95
	26.0	0.75	0.86	0.68	0.80
	26.0	0.65	0.78	0.61	0.75
	23.0	0.63	0.77	0.59	0.71
TBVOOS	100.0	1.00		0.97	
	90.0	1.00		--	
	50.0	0.92		0.87	
(FFTR/FHOOS included)		> 65%F	≤ 65%F	> 65%F	≤ 65%F
(Bounds operation with NFWT)	50.0	0.92	1.00	0.86	0.95
	26.0	0.75	0.86	0.68	0.80
	26.0	0.42	0.52	0.38	0.48
	23.0	0.38	0.47	0.35	0.43

25 Limits support operation with any combination of any 1 inoperable SRV, 2 inoperable TBV, up to 40% of the TIP channels out-of-service, and up to 50% of the LPRMs out-of-service. FHOOS not permitted in the MELLLA+ domain.

26 "--" indicates that the fuel limit has no breakpoint at this power.

Table 22

Framatome Fuel Flow-Dependent $LHGRFAC_f$ Multipliers[27]

Core Flow (% of rated)	ATRIUM 10XM and ATRIUM 11 $LHGRFAC_f$
0.0	0.52
31.0	0.52
75.0	1.00
107.0	1.00

27 Multipliers valid for all SCRAM insertion times and all core average exposure ranges.

Table 23

Framatome Fuel Steady-State $MAPLHGR_{SS}$ Limits[28, 29, 30]

Average Planar Exposure (GWd/MTU)	ATRIUM 10XM MAPLHGR (kW/ft)	ATRIUM 11 MAPLHGR (kW/ft)
0.0	13.1	12.0
15.0	13.1	--
20.0	--	12.0
60.0	--	9.0
67.0	7.7	--
69.0	N/A	7.2

28 Framatome Fuel MAPLHGR limits do not have a power, flow, or EOOS dependency.

29 ATRIUM 10XM MAPLHGR limits must be adjusted by a 0.80 multiplier when in SLO. ATRIUM 11 MAPLHGR limits must be adjusted by a 0.85 multiplier when in SLO. SLO not permitted for FHOOS, TBVOOS or MSIVOOS.

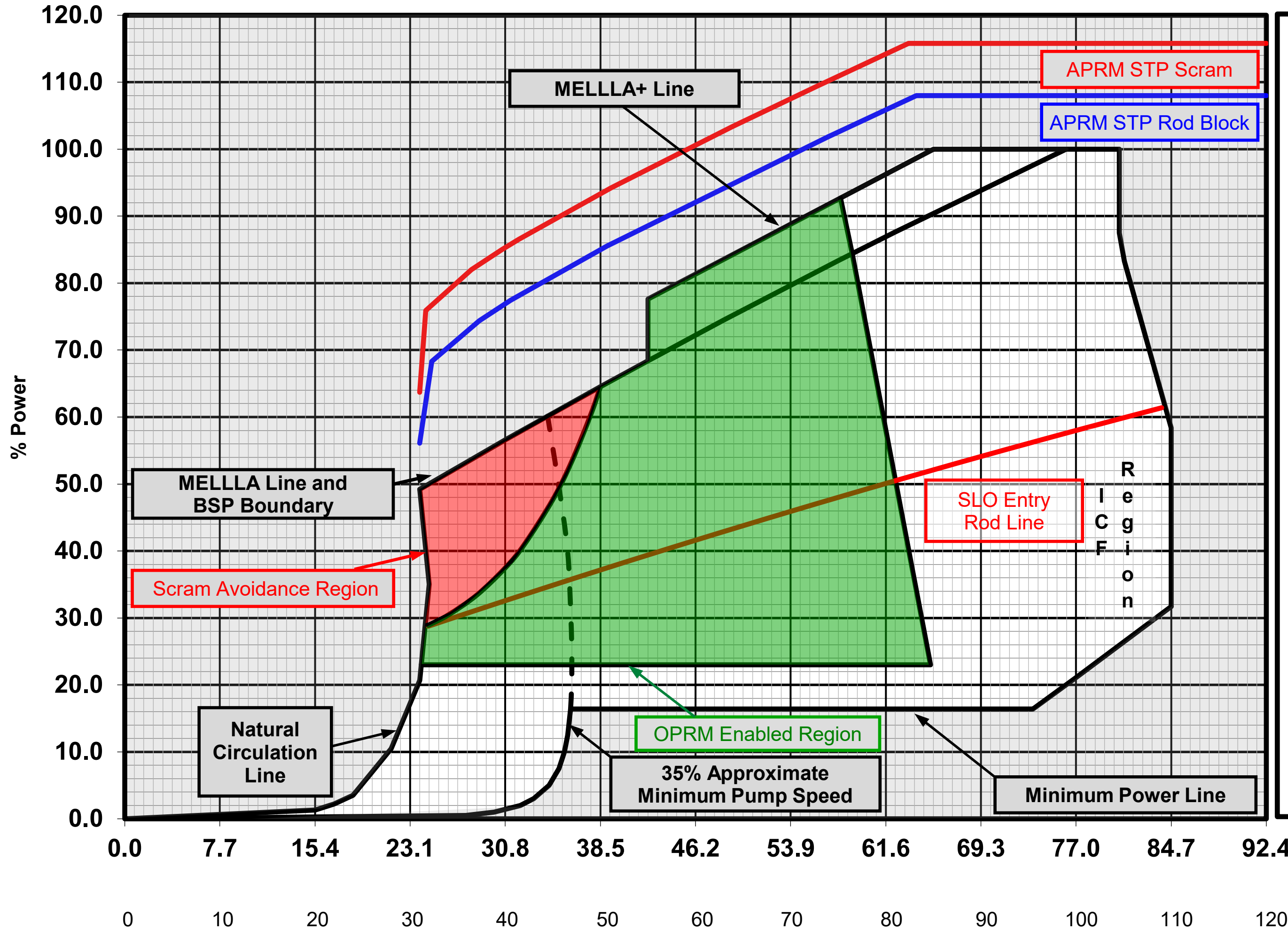
30 "--" indicates that the fuel limit has no breakpoint at this exposure.

Figure 1

MELLLA+ Power/Flow Map

OPRM Operable, Two Loop Operation, 2923 MWt

This Figure supports Improved Technical Specification 3.3.1.1 and the Technical Requirements Manual Specification 3.3



Power %	Minimum (MELLLA) Core Flow Mlbs/hr	Minimum (MELLLA+) Core Flow Mlbs/hr	Maximum (ICF) Core Flow Mlbs/hr
100	76.19	65.45	80.47
99	75.04	64.42	80.47
98	73.89	63.39	80.47
97	72.75	62.35	80.47
96	71.61	61.32	80.47
95	70.49	60.29	80.47
94	69.36	59.26	80.47
93	68.25	58.22	80.47
92	67.13	57.19	80.47
91	66.03	56.16	80.47
90	64.93	55.13	80.47
89	63.83	54.10	80.47
88	62.74	53.06	80.47
87	61.66	52.03	80.51
86	60.58	51.00	80.60
85	59.50	49.97	80.69
84	58.43	48.94	80.79
83	57.37	47.90	80.90
82	56.31	46.87	81.05
81	55.25	45.84	81.21
80	54.20	44.81	81.36
79	53.16	43.77	81.51
78	52.12	42.74	81.67
77	51.08	---	81.82
76	50.05	---	81.98
75	49.02	---	82.13
74	48.00	---	82.29
73	46.98	---	82.44
72	45.96	---	82.60
71	44.95	---	82.75
70	43.94	---	82.91
69	42.94	---	83.06
68	41.94	---	83.22
67	40.95	---	83.37
66	39.96	---	83.52
65	38.97	---	83.68
64	37.99	---	83.83
63	37.01	---	83.99
62	36.04	---	84.14
61	35.06	---	84.30
60	34.10	---	84.45
59	33.13	---	84.61
58	32.17	---	84.70

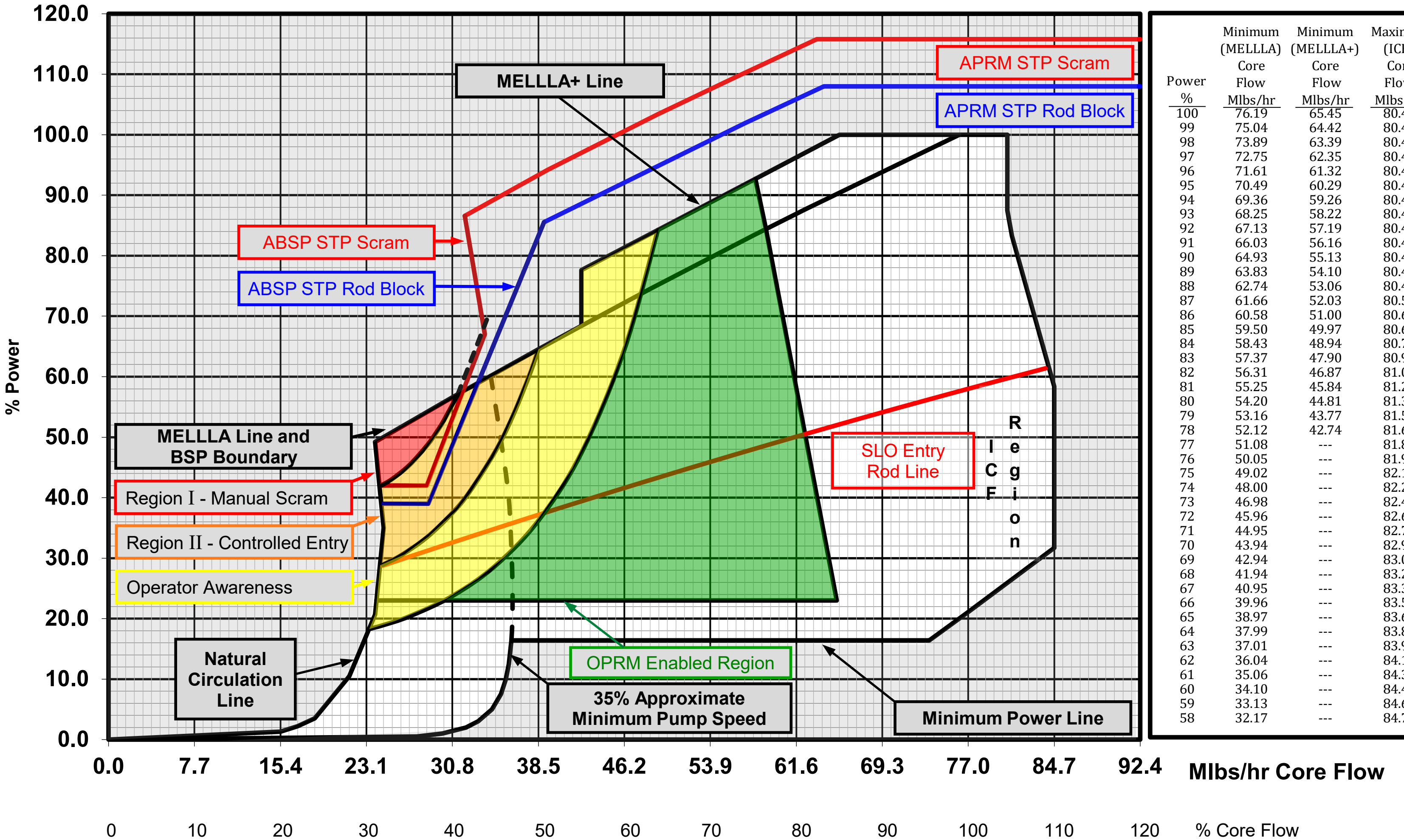
Reference: 0B21-2045, Revision 2

Figure 2

MELLLA+ Power/Flow Map

OPRM Inoperable, Two Loop Operation, 2923 MWt

This Figure supports Improved Technical Specification 3.3.1.1 and the Technical Requirements Manual Specification 3.3



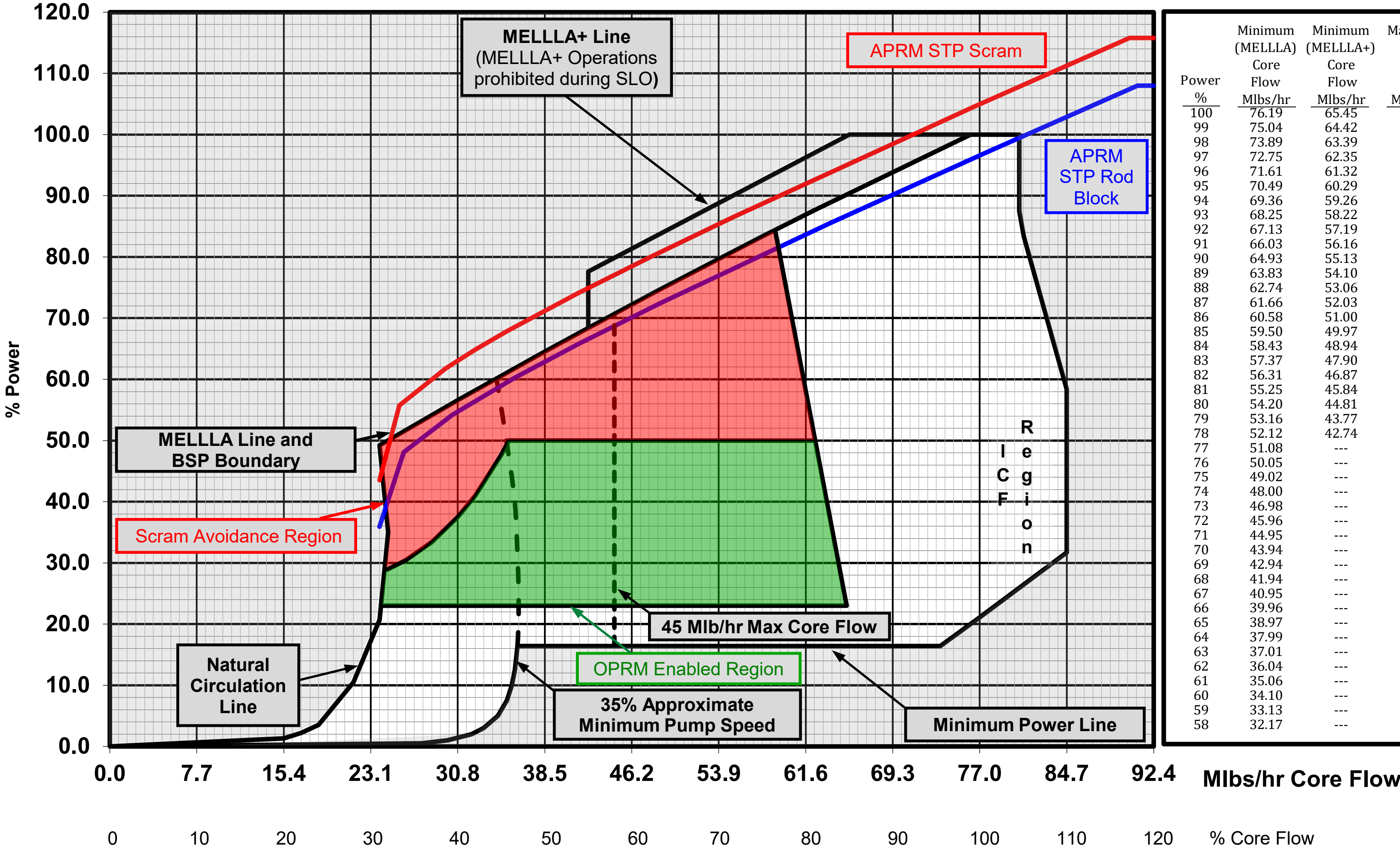
Power %	Minimum (MELLLA) Core Flow Mlbs/hr	Minimum (MELLLA+) Core Flow Mlbs/hr	Maximum (ICF) Core Flow Mlbs/hr
100	76.19	65.45	80.47
99	75.04	64.42	80.47
98	73.89	63.39	80.47
97	72.75	62.35	80.47
96	71.61	61.32	80.47
95	70.49	60.29	80.47
94	69.36	59.26	80.47
93	68.25	58.22	80.47
92	67.13	57.19	80.47
91	66.03	56.16	80.47
90	64.93	55.13	80.47
89	63.83	54.10	80.47
88	62.74	53.06	80.47
87	61.66	52.03	80.51
86	60.58	51.00	80.60
85	59.50	49.97	80.69
84	58.43	48.94	80.79
83	57.37	47.90	80.90
82	56.31	46.87	81.05
81	55.25	45.84	81.21
80	54.20	44.81	81.36
79	53.16	43.77	81.51
78	52.12	42.74	81.67
77	51.08	---	81.82
76	50.05	---	81.98
75	49.02	---	82.13
74	48.00	---	82.29
73	46.98	---	82.44
72	45.96	---	82.60
71	44.95	---	82.75
70	43.94	---	82.91
69	42.94	---	83.06
68	41.94	---	83.22
67	40.95	---	83.37
66	39.96	---	83.52
65	38.97	---	83.68
64	37.99	---	83.83
63	37.01	---	83.99
62	36.04	---	84.14
61	35.06	---	84.30
60	34.10	---	84.45
59	33.13	---	84.61
58	32.17	---	84.70

Reference: 0B21-2045, Revision 2

Figure 3
MELLLA+ Power/Flow Map

OPRM Operable, Single Loop Operation, 2923 MWt

This Figure supports Improved Technical Specification 3.3.1.1 and the Technical Requirements Manual Specification 3.3



Power %	Minimum (MELLLA) Core Flow Mlbs/hr	Minimum (MELLLA+) Core Flow Mlbs/hr	Maximum (ICF) Core Flow Mlbs/hr
100	76.19	65.45	80.47
99	75.04	64.42	80.47
98	73.89	63.39	80.47
97	72.75	62.35	80.47
96	71.61	61.32	80.47
95	70.49	60.29	80.47
94	69.36	59.26	80.47
93	68.25	58.22	80.47
92	67.13	57.19	80.47
91	66.03	56.16	80.47
90	64.93	55.13	80.47
89	63.83	54.10	80.47
88	62.74	53.06	80.47
87	61.66	52.03	80.51
86	60.58	51.00	80.60
85	59.50	49.97	80.69
84	58.43	48.94	80.79
83	57.37	47.90	80.90
82	56.31	46.87	81.05
81	55.25	45.84	81.21
80	54.20	44.81	81.36
79	53.16	43.77	81.51
78	52.12	42.74	81.67
77	51.08	---	81.82
76	50.05	---	81.98
75	49.02	---	82.13
74	48.00	---	82.29
73	46.98	---	82.44
72	45.96	---	82.60
71	44.95	---	82.75
70	43.94	---	82.91
69	42.94	---	83.06
68	41.94	---	83.22
67	40.95	---	83.37
66	39.96	---	83.52
65	38.97	---	83.68
64	37.99	---	83.83
63	37.01	---	83.99
62	36.04	---	84.14
61	35.06	---	84.30
60	34.10	---	84.45
59	33.13	---	84.61
58	32.17	---	84.70

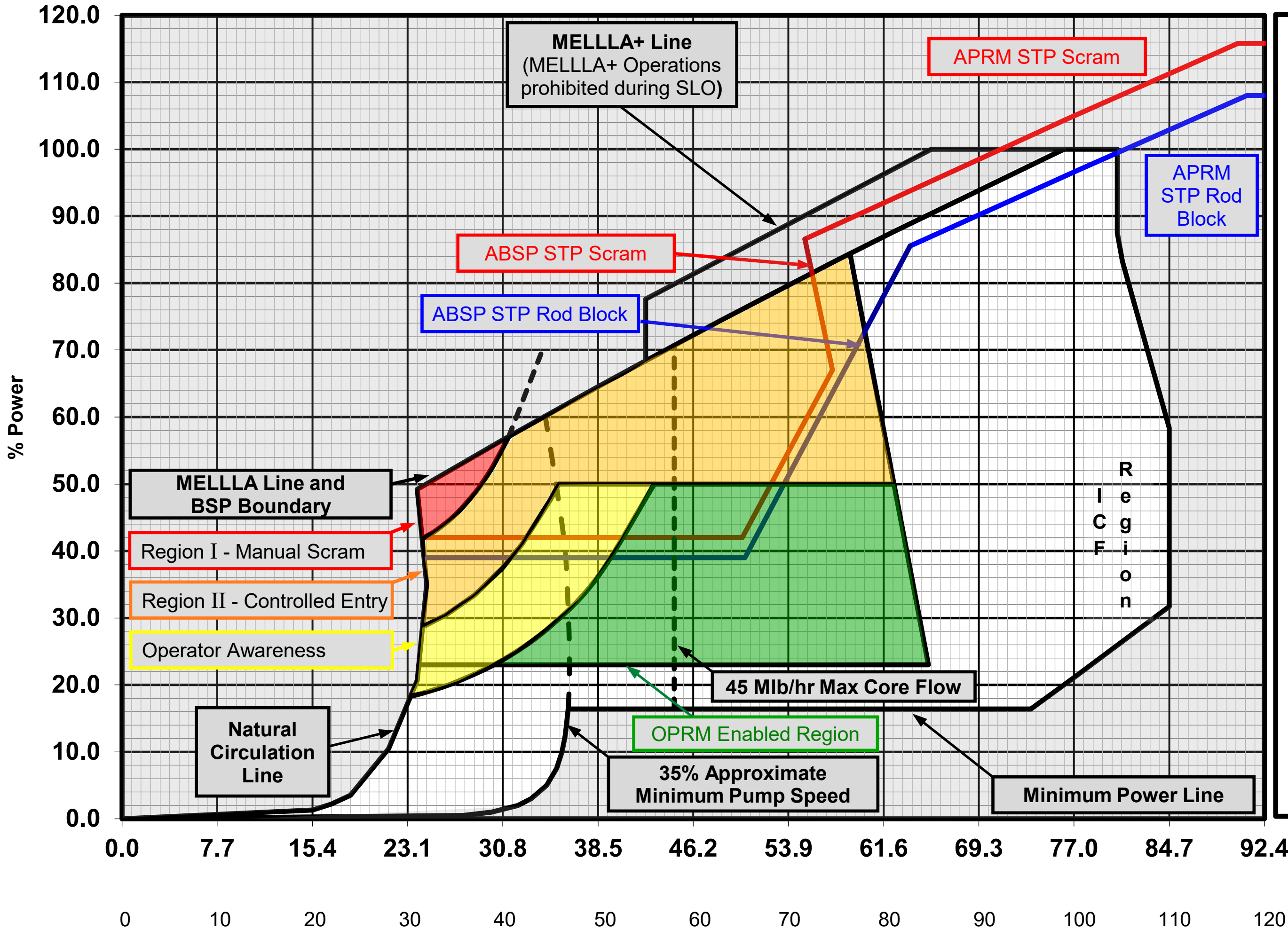
Reference: 0B21-2045, Revision 2

Figure 4

MELLLA+ Power/Flow Map

OPRM Inoperable, Single Loop Operation, 2923 MWt

This Figure supports Improved Technical Specification 3.3.1.1 and the Technical Requirements Manual Specification 3.3



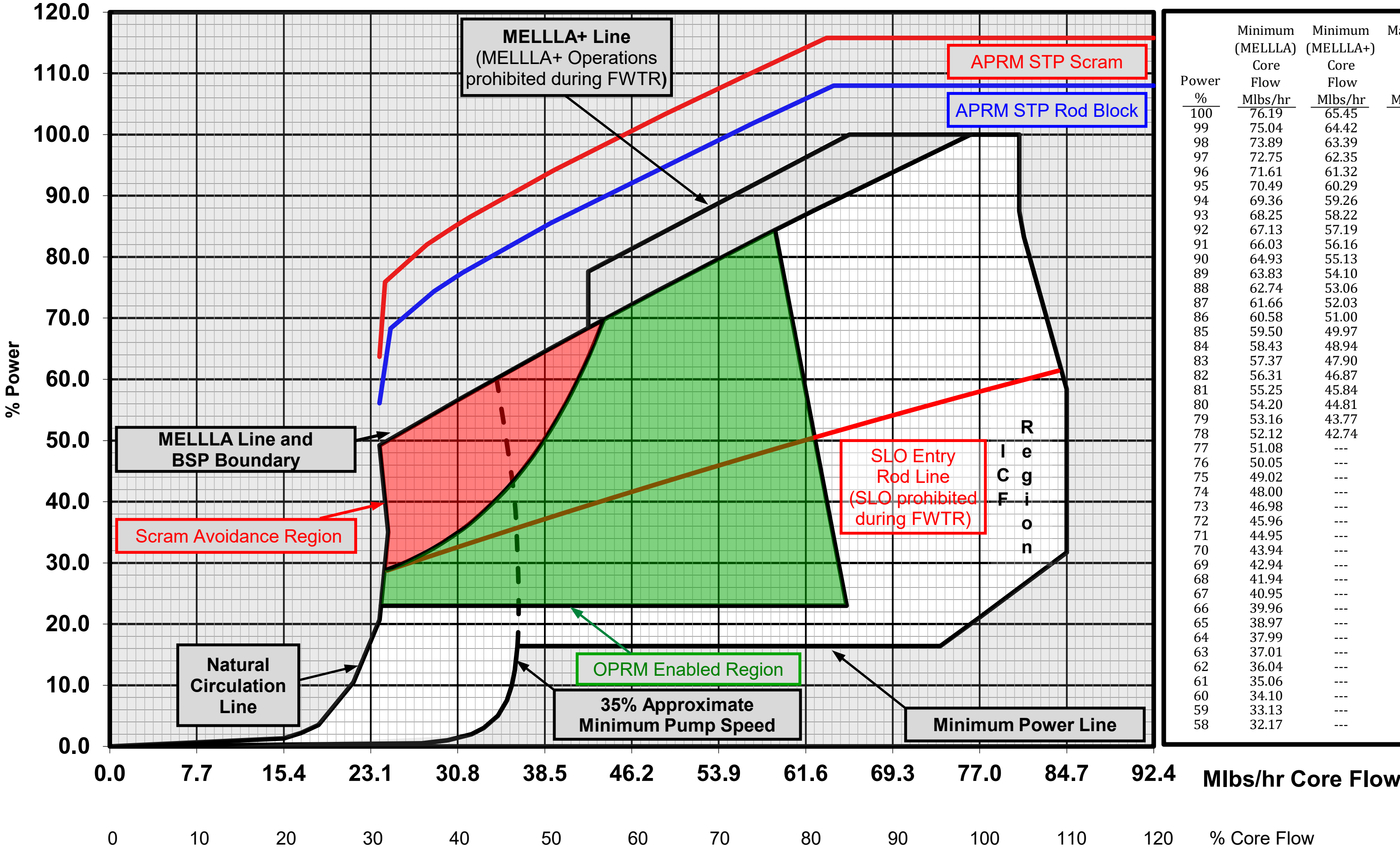
Power %	Minimum (MELLLA) Core Flow Mlbs/hr	Minimum (MELLLA+) Core Flow Mlbs/hr	Maximum (ICF) Core Flow Mlbs/hr
100	76.19	65.45	80.47
99	75.04	64.42	80.47
98	73.89	63.39	80.47
97	72.75	62.35	80.47
96	71.61	61.32	80.47
95	70.49	60.29	80.47
94	69.36	59.26	80.47
93	68.25	58.22	80.47
92	67.13	57.19	80.47
91	66.03	56.16	80.47
90	64.93	55.13	80.47
89	63.83	54.10	80.47
88	62.74	53.06	80.47
87	61.66	52.03	80.51
86	60.58	51.00	80.60
85	59.50	49.97	80.69
84	58.43	48.94	80.79
83	57.37	47.90	80.90
82	56.31	46.87	81.05
81	55.25	45.84	81.21
80	54.20	44.81	81.36
79	53.16	43.77	81.51
78	52.12	42.74	81.67
77	51.08	---	81.82
76	50.05	---	81.98
75	49.02	---	82.13
74	48.00	---	82.29
73	46.98	---	82.44
72	45.96	---	82.60
71	44.95	---	82.75
70	43.94	---	82.91
69	42.94	---	83.06
68	41.94	---	83.22
67	40.95	---	83.37
66	39.96	---	83.52
65	38.97	---	83.68
64	37.99	---	83.83
63	37.01	---	83.99
62	36.04	---	84.14
61	35.06	---	84.30
60	34.10	---	84.45
59	33.13	---	84.61
58	32.17	---	84.70

Reference: 0B21-2045, Revision 2

Figure 5
MELLLA+ Power/Flow Map

OPRM Operable, FWTR, 2923 MWt

This Figure supports Improved Technical Specification 3.3.1.1 and the Technical Requirements Manual Specification 3.3



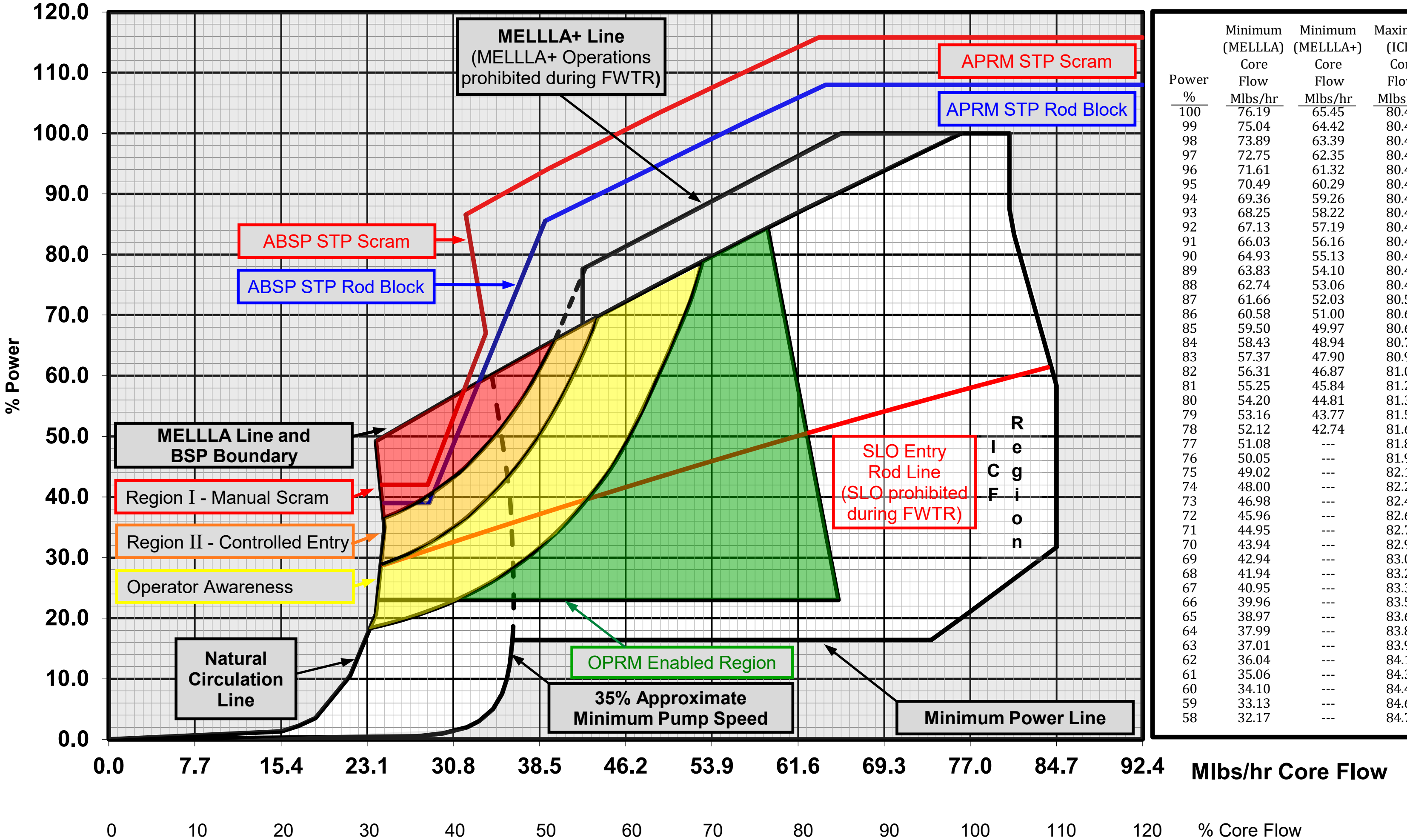
Power %	Minimum (MELLLA) Core Flow Mlbs/hr	Minimum (MELLLA+) Core Flow Mlbs/hr	Maximum (ICF) Core Flow Mlbs/hr
100	76.19	65.45	80.47
99	75.04	64.42	80.47
98	73.89	63.39	80.47
97	72.75	62.35	80.47
96	71.61	61.32	80.47
95	70.49	60.29	80.47
94	69.36	59.26	80.47
93	68.25	58.22	80.47
92	67.13	57.19	80.47
91	66.03	56.16	80.47
90	64.93	55.13	80.47
89	63.83	54.10	80.47
88	62.74	53.06	80.47
87	61.66	52.03	80.51
86	60.58	51.00	80.60
85	59.50	49.97	80.69
84	58.43	48.94	80.79
83	57.37	47.90	80.90
82	56.31	46.87	81.05
81	55.25	45.84	81.21
80	54.20	44.81	81.36
79	53.16	43.77	81.51
78	52.12	42.74	81.67
77	51.08	---	81.82
76	50.05	---	81.98
75	49.02	---	82.13
74	48.00	---	82.29
73	46.98	---	82.44
72	45.96	---	82.60
71	44.95	---	82.75
70	43.94	---	82.91
69	42.94	---	83.06
68	41.94	---	83.22
67	40.95	---	83.37
66	39.96	---	83.52
65	38.97	---	83.68
64	37.99	---	83.83
63	37.01	---	83.99
62	36.04	---	84.14
61	35.06	---	84.30
60	34.10	---	84.45
59	33.13	---	84.61
58	32.17	---	84.70

Reference: 0B21-2045, Revision 2

Figure 6
MELLLA+ Power/Flow Map

OPRM Inoperable, FWTR, 2923 MWt

This Figure supports Improved Technical Specification 3.3.1.1 and the Technical Requirements Manual Specification 3.3



Power %	Minimum (MELLLA) Core Flow Mlbs/hr	Minimum (MELLLA+) Core Flow Mlbs/hr	Maximum (ICF) Core Flow Mlbs/hr
100	76.19	65.45	80.47
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97	72.75	62.35	80.47
96	71.61	61.32	80.47
95	70.49	60.29	80.47
94	69.36	59.26	80.47
93	68.25	58.22	80.47
92	67.13	57.19	80.47
91	66.03	56.16	80.47
90	64.93	55.13	80.47
89	63.83	54.10	80.47
88	62.74	53.06	80.47
87	61.66	52.03	80.51
86	60.58	51.00	80.60
85	59.50	49.97	80.69
84	58.43	48.94	80.79
83	57.37	47.90	80.90
82	56.31	46.87	81.05
81	55.25	45.84	81.21
80	54.20	44.81	81.36
79	53.16	43.77	81.51
78	52.12	42.74	81.67
77	51.08	---	81.82
76	50.05	---	81.98
75	49.02	---	82.13
74	48.00	---	82.29
73	46.98	---	82.44
72	45.96	---	82.60
71	44.95	---	82.75
70	43.94	---	82.91
69	42.94	---	83.06
68	41.94	---	83.22
67	40.95	---	83.37
66	39.96	---	83.52
65	38.97	---	83.68
64	37.99	---	83.83
63	37.01	---	83.99
62	36.04	---	84.14
61	35.06	---	84.30
60	34.10	---	84.45
59	33.13	---	84.61
58	32.17	---	84.70

Reference: 0B21-2045, Revision 2

ANP-3897NP, *Brunswick Unit 2 Cycle 25 Reload Safety Analysis*, Revision 0 framatome

Brunswick Unit 2 Cycle 25 Reload Safety Analysis

ANP-3897NP
Revision 0

February 2021

Nature of Changes

Item	Section(s) or Page(s)	Description and Justification
1	All	Initial Issue

Contents

Tables

Figures

Nomenclature

ABSP	automated backup stability protection
APRM	average power range monitor
AOO	anticipated operational occurrence
ARO	all control rods out
ASME	American Society of Mechanical Engineers
AST	alternative source term
ATWS	anticipated transient without scram
ATWS-I	anticipated transient without scram with instability
ATWS-RPT	anticipated transient without scram recirculation pump trip
BEO-III	best estimate enhanced option III
BOC	beginning-of-cycle
BPWS	banked position withdrawal sequence
BSP	backup stability protection
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
EFPD	effective full-power days
EFPH	effective full-power hours
EOC	end-of-cycle
EOCLB	end-of-cycle licensing basis
EOFP	end of full power
EOOS	equipment out-of-service
FFTR	final feedwater temperature reduction
FHA	fuel handling accident
FHOOS	feedwater heaters out-of-service
FWCF	feedwater controller failure
GE	General Electric
GSF	generic shape function
HFCL	high flow control line
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

Nomenclature *(Continued)*

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
MSIVIS	main steam isolation valve in-service
MSIVOOS	main steam isolation 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
OOS	out-of-service
OPRM	oscillation power range monitor
P_{bypass}	power below which direct scram on TSV/TCV closure is bypassed
PCT	peak cladding temperature
PLU	power load unbalance
PRFDS	pressure regulator failure downscale
PRFO	pressure regulator failure open
PROOS	pressure regulator out-of-service
RBM	(control) rod block monitor
RDF	recirculation drive flow
RHR	residual heat removal
RPS	reactor protection system
RPT	recirculation pump trip
RTP	rated thermal power
SLC	standby liquid control
SLMCPR	safety limit minimum critical power ratio
SLO	single-loop operation
SRV	safety/relief valve
SRVOOS	safety/relief valve out-of-service
SS	steady state
STP	simulated thermal power
TBVOOS	turbine bypass valves out-of-service
TCV	turbine control valve
TIP	traversing incore probe
TLO	two-loop operation
TSSS	technical specifications scram speed
TSV	turbine stop valve
TTNB	turbine trip with no bypass
ΔCPR	change in critical power ratio
2PT	2 pump trip

1.0 INTRODUCTION

Reload licensing analyses results generated by Framatome Inc. are presented in support of Brunswick Unit 2 Cycle 25. The analyses reported in this document, with the exception of the ATWS I and stability methodologies, were performed using methodologies previously approved for generic application to boiling water reactors and demonstrated in Reference 1 to be applicable for ATRIUM 11 fuel operating in the MELLLA+ extended flow operating domain, Reference 2. The NRC technical limitations associated with the application of the approved methodologies have been satisfied by these analyses. The ATWS-I and stability methodologies were applied on a plant specific basis which has been approved by the NRC per the Reference 8 safety evaluation.

The Cycle 25 core consists of a total of 560 fuel assemblies, including 220 fresh ATRIUM 11 assemblies, and 340 irradiated ATRIUM 10XM assemblies. The licensing analysis supports the core design presented in Reference 3 and the use of the MELLLA+ operating domain.

The Cycle 25 reload licensing analyses were performed for the potentially limiting events and analyses that were identified in the disposition of events. The results of the analyses are used to establish the Technical Specifications/COLR limits and ensure that the design and licensing criteria are met. The design and safety analyses are based on the design and operational assumptions and plant parameters provided by the utility. The results of the reload licensing analysis support operation for the power/flow map presented in Figure 1.1. This reload licensing also supports operation with the equipment out-of-service (EOOS) scenarios presented in Table 1.1.

The results in this report comply with the license condition related to the range of applicability for the channel bow model. This license condition was added with the inclusion of the SAFLIM3D methodology to the list of approved references in Section 5.6.5(b) of the Brunswick Technical Specifications.

Table 1.1 EOOS
Operating Conditions*

Single-loop operation (SLO)†, ‡
Turbine bypass valves out-of-service (TBVOOS)
Feedwater heaters out-of-service (FHOOS)†
One safety relief valve out-of-service (SRVOOS)
One main steam isolation valve out-of-service§ (MSIVOOS)
One pressure regulator out-of-service**
Up to 40% of the TIP channels out-of-service (100% available at startup)
Up to 50% of the LPRMs out-of-service

* Each EOOS condition is supported in combination with 1 SRVOOS, up to 40% of the TIP channels out-of-service, and/or up to 50% of the LPRMs out-of-service.

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

‡ Operation in SLO is only supported up to a maximum power level of 71.1% of rated.

§ Operation with one MSIVOOS is only supported at power levels less than 70% of rated.

** Operation with one pressure regulator out-of-service is only supported at power levels greater than 90% of rated and less than 50% of rated.

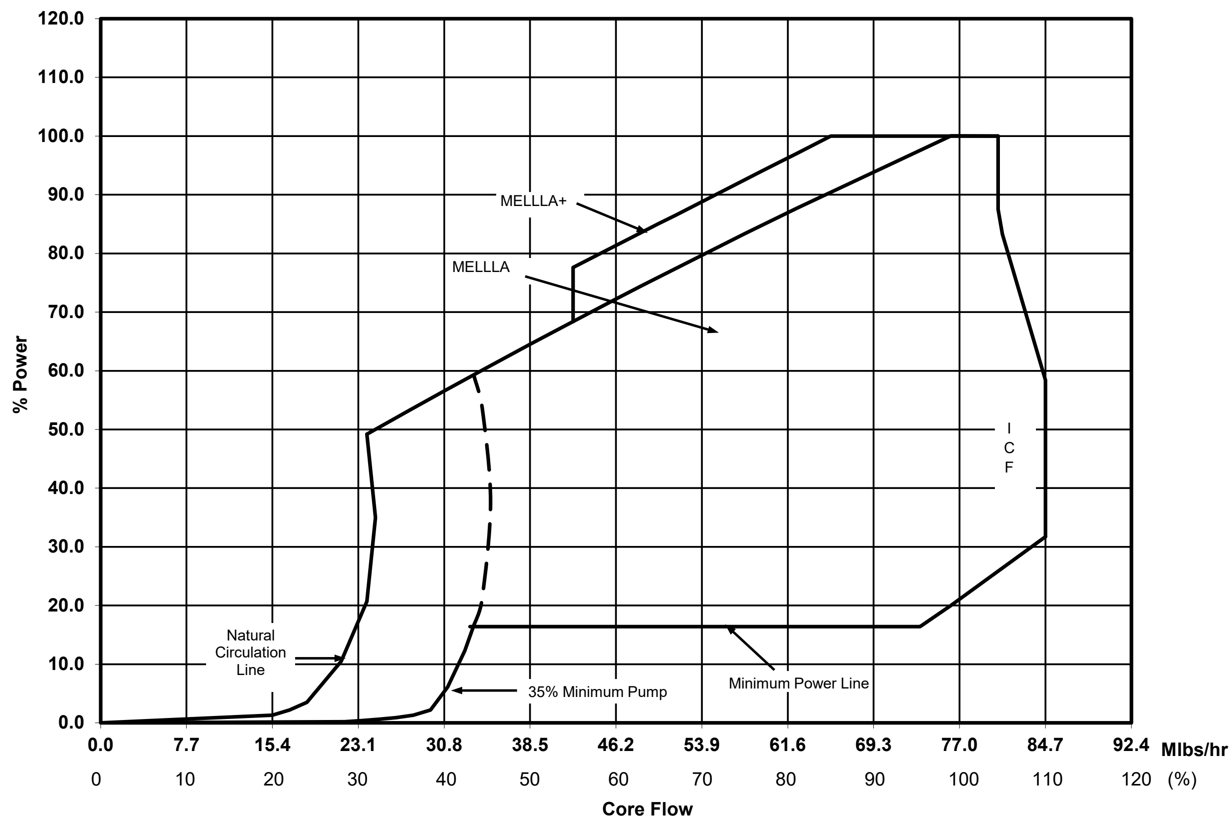

Figure 1.1 Brunswick Unit 2 Power/Flow Map

2.0 DISPOSITION OF EVENTS AND PLANT MODELING SENSITIVITIES

2.1 *Disposition of Events for ATRIUM 11 Fuel Introduction*

A disposition of events to identify the limiting events which need to be analyzed to support operation at the Brunswick Steam Electric Plant was performed for the introduction of ATRIUM 11 fuel. Events and analyses identified as potentially limiting were either evaluated generically for the introduction of ATRIUM 11 fuel or are performed on a cycle-specific basis. The results of the disposition of events are presented in Tables 2.1 and 2.2 of Reference 38.

The plant parameter differences between those used in the Brunswick Unit 2 Cycle 24 analyses and the planned analyses for the Brunswick Unit 2 Cycle 25 reload were reviewed to determine if the conclusions of the disposition of events remain applicable. The review concluded that analyses affected by the differences were included in Reference 4.

2.2 *Plant Specific Modeling Sensitivities*

As part of the initial application of the AURORA-B AOO methodology to a plant, justification must be provided to ensure that conservative plant parameters are being used. This requirement is defined in Limitation and Conditions 7 and 11 of the Reference 19 safety evaluation. In particular, these limitations and conditions state:

7. As discussed in Section 3.6 of this SE, licensees should provide justification for the key plant parameters and initial conditions selected for performing sensitivity analyses on an event-specific basis. Licensees should further justify that the input values ultimately chosen for these key plant parameters and initial conditions will result in a conservative prediction of FoMs when performing calculations according to the AURORA-B EM described in ANP-10300P.

11. AREVA will provide justification for the uncertainties used for the highly ranked plant-specific PIRT parameters C12, R01, R02, and SL02 on a plant-specific basis, as described in Table 3.2 of this SE.

In order to comply with these requirements, a set of sensitivity studies was performed. Separate sensitivity studies were performed for each of the three figures of merit that were required to license the initial transition to ATRIUM 11 fuel at Brunswick (Brunswick Unit 1 Cycle 23): ΔMCPR (Table 2.3 of Reference 38), transient nodal power (Table 2.4 of Reference 38), and overpressure (Table 2.5 of Reference 38). These sensitivity studies address the key parameters required for licensing with the exception of C12 which is described below. These sensitivity studies remain applicable for Brunswick Unit 2 Cycle 25. In addition to these sensitivity studies, licensing calculations will also look at a wide range of core exposures and flow rates to ensure that the conservative statepoints have been analyzed.

Uncertainties associated with PIRT parameters R01, R02, and SL02 were evaluated for the initial transition (Section 2.2 of Reference 38). The conclusions made from that evaluation remain applicable for Brunswick Unit 2 Cycle 25.

In addition to these plant parameter sensitivities, the sensitivity of the transient results to initial control rod position (PIRT parameter C12) was examined in the initial transition of ATRIUM 11 fuel at Brunswick (Section 2.2 of Reference 38). The process developed for the initial transition remains applicable for Brunswick Unit 2 Cycle 25.

Limitation and Condition 16 of the Reference 19 SE, given below, also requires a plant specific justification.

16. [ ] *is not sampled as part of the methodology, justification should be provided on a plant-specific basis that a conservative flow rate has been assumed* [ ].

The [ ] is provided by Duke and accounts for [ ]. The AURORA-B model [ ]

3.0 MECHANICAL DESIGN ANALYSIS

The mechanical design analyses for ATRIUM 10XM and ATRIUM 11 fuel assemblies are presented in the applicable mechanical design reports (References 5, 6, 7, and 36). The maximum exposure limits for the ATRIUM 10XM and ATRIUM 11 fuel designs are:

54.0 GWd/MTU average assembly exposure (ATRIUM 10XM)
57.0 GWd/MTU average assembly exposure (ATRIUM 11)

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

The ATRIUM 10XM and ATRIUM 11 LHGR limits are presented in Section 8.0. The fuel cycle design analyses (Reference 3) have verified that the ATRIUM 10XM and ATRIUM 11 fuel assemblies remain within licensed burnup limits.

4.0 THERMAL-HYDRAULIC DESIGN ANALYSIS

4.1 *Thermal-Hydraulic Design and Compatibility*

The results of the thermal-hydraulic characterization and compatibility analyses are presented in the thermal-hydraulic design report (Reference 9). The analysis results demonstrate that the thermal-hydraulic design and compatibility criteria are satisfied for the Brunswick Unit 2 transition core consisting of ATRIUM 10XM and ATRIUM 11 fuel assemblies.

4.2 *Safety Limit MCPR Analysis*

The safety limit $MCPR_{99.9\%}$ (SLMCPR) is defined as the minimum value of the critical power ratio which ensures that less than 0.1% of the fuel rods in the core are expected to experience boiling transition during normal operation or an anticipated operational occurrence (AOO). The SLMCPR for all fuel in the Brunswick Unit 2 Cycle 25 core was determined using the methodology described in Reference 10. The analysis was performed with a power distribution that conservatively represents expected reactor operating states that could both exist at the MCPR operating limit and produce a MCPR equal to the SLMCPR during an AOO.

The Brunswick Unit 2 Cycle 25 SLMCPR analysis used the ACE/ATRIUM 10XM critical power correlation additive constants and additive constant uncertainty described in Reference 11 for the ATRIUM 10XM fuel. The ACE/ATRIUM 11 critical power correlation, described in Reference 12, was applied to the ATRIUM 11 fuel assemblies.

In the Framatome methodology, the effects of channel bow on the critical power performance are accounted for in the SLMCPR analysis. Reference 10 discusses the application of a realistic channel bow model.

The fuel- and plant-related uncertainties used in the SLMCPR analysis are presented in Table 4.1. The radial power uncertainty used in the analysis includes the effects of up to 40% of the TIP channels out-of-service, up to 50% of the LPRMs out-of-service, and a 2500 EFPH LPRM calibration interval. For TLO, analyses were performed for the minimum and maximum core flow conditions associated with rated power (85% and 104.5%), as well as the maximum core power at 55% core flow for the Brunswick power/flow map, Figure 1.1. For the maximum core flow statepoint, the TLO core flow uncertainty given in Table 4.1 was used. For the minimum core flow at full power, and 55% core flow statepoints, the SLO core flow uncertainty in Table 4.1 was used consistent with the restrictions listed in Section 2.2.1.1 of the Reference 2 Safety Evaluation Report.

The analysis results support a two-loop operation (TLO) SLMCPR of 1.08 and a single-loop operation (SLO) SLMCPR of 1.09. Table 4.2 presents a summary of the analysis results including the SLMCPR and the percentage of rods expected to experience boiling transition.

4.3 *Core Hydrodynamic Stability*

Brunswick Unit 2 will implement a plant specific application of the Best-estimate Enhanced Option III (BEO-III) analysis methodology to support operation using the Confirmation Density Algorithm (CDA) as described in References 16 and 17. The CDA enabled through the OPRM system and the BSP solution described in References 16 and 17 will be the stability licensing basis for Brunswick. Cycle-specific analyses have been performed with RAMONA5-FA modeling recirculation pump trips from limiting MELLLA+, MELLLA with FHOOS and SLO statepoints. The LPRM traces for limiting cases were analyzed with the CDA by Duke Energy consistent with the Reference 16 methodology. The minimum required TLO and SLO stability operating limits are 1.15 and 1.19, respectively. There were no cases within the 95/95 population which produced a channel decay ratio greater than 1.0. The cycle-specific analyses have been performed consistent with the conditions provided by the NRC in Reference 37.

The Backup Stability Protection (BSP) solution may be used by the plant in the event that the OPRM system is declared inoperable. Reference 16 Section 5 describes two BSP options that are based on selected elements from three distinct constituents: BSP Manual Regions, BSP Boundary, and Automated BSP (ABSP) setpoints.

The Manual BSP region boundaries were validated for Brunswick Unit 2 Cycle 25 using STAIF (Reference 15 with modified fuel rod properties documented in Reference 17) for nominal and reduced feedwater temperature operation. 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).

The ABSP Average Power Range Monitor (APRM) Simulated Thermal Power (STP) setpoints associated with the ABSP Scram Region are listed in Table 4.5. These ABSP setpoints are applicable to both TLO and SLO as well as nominal and reduced feedwater temperature operation.

4.4 *Voiding in the Channel Bypass Region*

To demonstrate compliance with the NRC's requirement that there be less than 5% bypass voiding around the LPRMs (see Section 5.1.1.5.1 of the Reference 2 Safety Evaluation), the bypass void level has been evaluated throughout the cycle. The maximum bypass void value applicable to the Cycle 25 design [

]

[

]

Table 4.1 Fuel- and Plant-Related Uncertainties for Safety Limit MCPR Analyses

Parameter	Uncertainty
Fuel-Related Uncertainties	
[ ]	
Plant-Related Uncertainties	
Feedwater flow rate	1.8%
Feedwater temperature	0.8%
Core pressure	0.8%
Total core flow rate TLO SLO	 2.5% 6.0%

[ ]

Table 4.2 Results Summary for Safety Limit MCPR Analyses

Power/Flow (%)	Minimum Supported SLMCPR*	Percentage of Rods in Boiling Transition
[ ]	TLO – 1.08	0.0720
[ ]	TLO – 1.07	0.0972
[ ]	TLO – 1.08	0.0954
[ ]	SLO – 1.09	0.0738

* The OLMCPR shown in Tables 8.1 through 8.9 were developed assuming a TLO SLMCPR of 1.08 and a SLO SLMCPR of 1.09.

Table 4.3 BSP Endpoints For Nominal Feedwater Temperature

Endpoint	Power (%)	Flow (%)	Definition
A1	57.0	40.6	Scram Region Boundary, HFCL
B1	42.0	31.7	Scram Region Boundary, NCL
A2	64.5	50.0	Controlled Entry Region Boundary, HFCL
B2	28.9	31.9	Controlled Entry Region Boundary, NCL

Table 4.4 BSP Endpoints For Reduced Feedwater Temperature

Endpoint	Power (%)	Flow (%)	Definition
A1	65.9	51.8	Scram Region Boundary, HFCL
B1	36.5	31.9	Scram Region Boundary, NCL
A2	69.8	56.8	Controlled Entry Region Boundary, HFCL
B2	28.9	31.9	Controlled Entry Region Boundary, NCL

Table 4.5 ABSP Setpoints for the Scram Region

Parameter	Symbol	Value
Slope of ABSP APRM flow-biased trip linear segment.	m_{TRIP}	2.00 %RTP/%RDF
ABSP APRM flow-biased trip setpoint power intercept. Constant Power Line for Trip from zero Drive Flow to Flow Breakpoint value.	$P_{BSP-TRIP}$	42.0 %RTP
ABSP APRM flow-biased trip setpoint drive flow intercept. Constant Flow Line for Trip.	$W_{BSP-TRIP}$	≥ 37.5 %RDF
Flow Breakpoint value	$W_{BSP-BREAK}$	25.0 %RDF

Table 4.6 Maximum Bypass Voiding at LPRM Level D*

Power (%) Flow (%) Condition	Cycle Exposure (GWd/MTU)	Bypass Void (%)
[		]

* The voiding at LPRM level D bounds the voiding at LPRM levels A, B, and C.

5.0 ANTICIPATED OPERATIONAL OCCURRENCES

This section describes the analyses performed to determine the power- and flow-dependent MCPR operating limits for base case operation for Brunswick Unit 2 Cycle 25.

The AURORA-B methodology (Reference 19) is used with the Framatome THERMEX methodology (Reference 20) for the generation of thermal limits. AURORA-B is a comprehensive evaluation model developed for predicting the dynamic response of boiling water reactors (BWRs) during transient, postulated accident, and beyond design-basis accident scenarios. The evaluation model (EM) contains a multi-physics code system with flexibility to incorporate all the necessary elements for analysis of the full spectrum of BWR events that are postulated to affect the nuclear steam supply system of the BWR plant. Deterministic analysis principles are applied to satisfy plant operational and Technical Specification requirements through the use of conservative initial conditions and boundary conditions.

The foundation of AURORA-B AOO is built upon three computer codes, S-RELAP5, MB2-K, and RODEX4. Working together as a system, they make up the multi-physics evaluation model that provides the necessary systems, components, geometries, processes, etc. to assure adequate predictions of the relevant BWR event characteristics for its intended applications. The three codes making up the foundation of the code system are:

- S-RELAP5 – This code provides the transient thermal-hydraulic, thermal conduction, control systems, and special process capabilities (i.e. valves, jet-pumps, steam separator, critical power correlations, etc.) necessary to simulate a BWR plant.

- MB2-K – This code uses advanced nodal expansion methods to solve the three-dimensional, two-group, neutron kinetics equations. The MB2-K code is consistent with the MICROBURN-B2 steady state core simulator. MB2-K receives a significant portion of its input from the steady state core simulator.

- RODEX4 – A subset of routines from this code are used to evaluate the transient thermal-mechanical fuel rod (including fuel/clad gap) properties as a function of temperature, rod internal pressure, etc. The fuel rod properties are used by S-RELAP5 when solving the transient thermal conduction equations in lieu of standard S-RELAP5 material property tables.

The AURORA-B AOO methodology (Reference 19) includes an evaluation of the impact of code uncertainties on Figures of Merit (FoM) (e.g. ∆MCPR, peak pressure) [ ] that has wide acceptance in the nuclear industry.

The ACE/ATRIUM 10XM critical power correlation (Reference 11) is used to evaluate the thermal margin for the ATRIUM 10XM fuel. The ACE/ATRIUM 11 critical power correlation (Reference 12) is used in the thermal margin evaluations for the ATRIUM 11 fuel.

5.1 *System Transients*

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

At Brunswick, 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}). Scram will occur when the high pressure or high neutron flux scram setpoint is reached. Reference 22 indicates that MCPR limits only need to be monitored at power levels greater than or equal to 23% of rated, which is the lowest power analyzed for this report.

The limiting exposure for rated power pressurization transients is typically at end of full power (EOFP) when the control rods are fully withdrawn. The end-of-cycle licensing basis (EOCLB) analysis was performed at EOFP + 15 EFPD. Analyses were performed at cycle exposures prior to EOCLB to ensure that the operating limits provide the necessary protection. Analyses were also performed to support extended cycle operation with final feedwater temperature reduction (FFTR) and power coastdown. The Brunswick Unit 2 Cycle 25 licensing basis exposures used to develop the limits breakpoints are presented in Table 5.1.

All pressurization transients assumed that one of the lowest setpoint safety relief valves (SRV) was inoperable. This basis supports operation with 1 SRV out-of-service.

The Brunswick Unit 2 turbine bypass system includes ten bypass valves. However, for base case analyses in which credit is taken for turbine bypass operation, only eight of the turbine bypass valves are assumed operable.

Reductions in feedwater temperature of less than or equal to 10°F from the nominal feedwater temperature and variation of ± 10 psi in dome pressure are considered base case operation, not an EOOS condition. This decrease in feedwater temperature causes a small increase in the core inlet subcooling which changes the axial power shape and core void fraction. In addition, the steam flow for a given power level decreases since more power is used to increase the coolant enthalpy to saturated conditions. The consequences of the FWCF event can be more severe as a result of the increase in core inlet subcooling during the overcooling phase of the event. Analyses were performed to evaluate the impact of reduced feedwater temperature on the FWCF event. While a decrease in steam flow tends to make the LRNB event less severe, the TCV initial position is further closed which tends to make the event more severe, especially at higher power levels. LRNB and TTNB events for base case operation were evaluated for both nominal and 10°F reduced feedwater temperatures. The analyses were performed with the limiting feedwater and dome pressure 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 110.3°F at rated power. Analyses were performed to support both nominal ± 10 psi and constant rated dome pressure with combined FFTR/Coastdown operation to the maximum licensing exposure (Table 5.1). The FWCF analyses were performed with the lowest feedwater temperature associated with the initial power level. Operation with FFTR is not allowed in the MELLLA+ extension of the Brunswick operating domain.

The results of the system pressurization transients are sensitive to the scram speed used in the calculations. 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 nominal scram speed (NSS) insertion times, extended scram speed (ESS), and the Technical Specifications scram speed (TSSS) insertion times used in the analyses are presented in Table 5.2. The NSS or ESS $MCPR_p$ limits can only be applied if the scram speed test results meet their respective insertion times. System transient analyses were performed to establish $MCPR_p$ limits for NSS, ESS, and TSSS insertion times. The Brunswick Unit 2 Technical Specifications (Reference 22) allow for operation with up to 10 “slow” and 1 stuck control rod. One additional control rod is assumed to fail to scram. The NSS, ESS, and TSSS analyses were performed to conservatively account for the effect of the slow and stuck rods on scram reactivity. For transient events below 50% power without direct scram, the results are relatively insensitive to scram speed, and only TSSS analyses are performed.

Tables 5.10, 5.11, and 5.12 present the limiting LHGRFACp transient analysis results for base case operation used to develop the operating limits for NSS, ESS, and TSSS insertion times, respectively.

5.1.1 Load Rejection No Bypass (LRNB)

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

For power levels less than 50% of rated, the LRNB analyses assume that the power load unbalance (PLU) is inoperable. With the PLU inoperable, the LRNB sequence of events is different than the standard event. Instead of a fast closure, the TCVs close in servo mode and there is no direct scram on TCV closure. The power and pressure excursion continues until the high pressure scram occurs. Given that there is no direct scram when the PLU is inoperable, the above and below P_{bypass} system responses at 26% power are identical.

LRNB analyses were performed for a range of power/flow conditions to support generation of the thermal limits. Tables 5.3, 5.4, and 5.5 present the base case limiting transient event and results as a function of power used to generate the EOCLB operating limits for NSS, ESS, and TSSS insertion times, respectively. Figures 5.1 – 5.3 show the responses of various reactor and plant parameters during the LRNB event initiated at 100% of rated power and 104.5% of rated core flow with TSSS insertion times at EOCLB.

5.1.2 Turbine Trip No Bypass (TTNB)

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

TTNB analyses were performed for a range of power/flow conditions for which the TTNB event is potentially limiting to support generation of the thermal limits. Tables 5.3, 5.4 , and 5.5 present the base case limiting transient event and results as a function of power used to generate the EOCLB operating limits for NSS, ESS, and TSSS insertion times, respectively. Figures 5.4 – 5.6 show the responses of various reactor and plant parameters during the TTNB event initiated at 100% of rated power and 104.5% of rated core flow with TSSS insertion times at EOCLB.

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 that results from the FWCF. The high water level trip causes the turbine stop valves to close in order to prevent damage to the turbine from excessive liquid inventory in the steam line. The valve closures create a compression wave that travels to the core causing a void collapse and subsequent rapid power excursion. The closure of the turbine stop valves also initiates a reactor scram. Eight of the ten installed turbine bypass valves are assumed operable and provide pressure relief. The core power excursion is mitigated in part by the pressure relief, but the primary mechanism for termination of the event is reactor scram.

FWCF analyses were performed for a range of power/flow conditions to support generation of the thermal limits. Tables 5.3, 5.4 , and 5.5 present the base case limiting transient event and results as a function of power used to generate the EOCLB operating limits for NSS, ESS, and TSSS insertion times, respectively. Figures 5.7 – 5.9 show the responses of various reactor and plant parameters during the FWCF event initiated at 100% of rated power and 104.5% of rated core flow with TSSS insertion times at EOCLB.

5.1.4 Pressure Regulator Failure Downscale (PRFDS)

The pressure regulator failure downscale event occurs when the pressure regulator system fails and sends a signal to close all four turbine control valves in control mode. Normally, a backup pressure regulator device would take control and maintain the setpoint pressure, resulting in a mild pressure excursion and a benign event. If 5 of the 6 pressure regulator devices were out-of-service, there would be no backup pressure regulator device and the event would be more severe. The core would pressurize resulting in void collapse and a subsequent power increase. The event would be terminated by scram when either the high-neutron flux or high-pressure setpoint is reached. Operation with only one pressure regulator device is not supported for Brunswick Unit 2 over the entire power/flow map. However, Duke Energy requested that Framatome review the PRFDS event with one pressure device in service to determine if it is bound by the LRNB event at power levels greater than 90% of rated and less than 50% of rated. Analysis results demonstrate that the LRNB is more limiting at power levels greater than 90% of rated. Since LRNB analyses assume the PLU is inoperable below 50% of rated power, the TCVs close in servo or control mode without a direct scram on fast closure. Therefore, the consequences of the PRFDS event with 5 of the 6 pressure regulators out of service are no more severe than the LRNB event at power levels less than 50% of rated.

5.1.5 Loss of Feedwater Heating

The loss of feedwater heating (LFWH) event analysis supports an assumed 100°F decrease in the feedwater temperature. The result is an increase in core inlet subcooling, which reduces voids, thereby increasing core power and shifting the axial power distribution toward the bottom of the core. As a result of the axial power shift and increased core power, voids begin to build up in the bottom region of the core, acting as negative feedback to the increased subcooling effect. The negative feedback moderates the core power increase. Although there is a substantial increase in core thermal power during the event, the increase in steam flow is much less because a large part of the added power is used to overcome the increase in inlet subcooling. The increase in steam flow is accommodated by the pressure control system via the TCVs or the turbine bypass valves, so no pressurization occurs. For Brunswick Unit 2 Cycle 25, a cycle-specific analysis was performed in accordance with the Reference 23 methodology to determine the change in MCPR for the event. The LFWH results are presented in Table 5.6.

5.1.6 Control Rod Withdrawal Error

The control rod withdrawal error (CRWE) transient is an inadvertent reactor operator initiated withdrawal of a control rod. This withdrawal increases local power and core thermal power, lowering the core MCPR. The CRWE transient is typically terminated by control rod blocks initiated by the rod block monitor (RBM). The CRWE event was analyzed assuming no xenon and allowing credible instrumentation out-of-service in the rod block monitor (RBM) system. The analysis further assumes that the plant could be operating in either an A or B sequence control rod pattern. The rated power CRWE results are shown in Table 5.7 for selected analytical RBM high power setpoint values from 108% to 117%. An assumed RBM high power setpoint of 114% was used to develop the $MCPR_p$ limits. At the corresponding intermediate and lower power setpoint values, the $MCPR_p$ values bound, or are equal to, the CRWE MCPR values. Framatome analyses show that standard filtered RBM setpoint reductions are supported. Analyses demonstrate that the 1% strain and centerline melt criteria are met with the LHGR limits presented in Section 8.2. The recommended operability requirements based on the unblocked CRWE results are shown in Table 5.8 based on the SLMCPR values presented in Section 4.2.

5.2 *Slow Flow Runup Analysis*

Flow-dependent MCPR and LHGR limits are established to support operation at off-rated core flow conditions. The limits are based on the CPR and heat flux changes experienced by the fuel during slow flow excursions. The slow flow excursion event assumes a failure of the recirculation flow control system such that the core flow increases slowly to the maximum flow physically permitted 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. Operation with one MSIVOOS causes a larger increase in pressure and power during the flow excursion which results in a steeper flow runup path. A conservatively steep flow runup path was used in the analysis. The slow flow runup analyses were performed to support operation in all the EOOS scenarios.

XCOBRA is used to calculate the change in critical power ratio during a two-loop flow runup to the maximum flow rate. The $MCPR_f$ limit is set such that the increase in core power, resulting from the maximum increase in core flow, assures that the TLO safety limit MCPR is not violated. Calculations were performed for a range of initial flow rates to determine the corresponding

MCPR values that put the limiting assembly on the safety limit MCPR at the high flow condition at the end of the flow excursion.

Results of the flow runup analysis are presented in Table 5.9. $MCPR_f$ limits that provide the required protection are presented in Table 8.10 and 8.11. The $MCPR_f$ limits are applicable for all Cycle 25 exposures.

Flow runup analyses were performed with CASMO-4/MICROBURN-B2 to determine flow-dependent LHGR multipliers ($LHGRFAC_f$) for ATRIUM 10XM and ATRIUM 11 fuel. The analysis assumes that the recirculation flow increases slowly along the limiting rod line to the maximum flow physically permitted 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. The $LHGRFAC_f$ multipliers are established to provide protection against fuel centerline melt and overstraining of the cladding during a flow runup. The Cycle 25 $LHGRFAC_f$ multipliers are presented in Table 8.19.

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

5.3 *Equipment Out-of-Service Scenarios*

The equipment out-of-service (EOOS) scenarios supported for Brunswick Unit 2 Cycle 25 are presented in Table 1.1 and discussed further in the following subsections. Tables 5.10, 5.11, and 5.12 present the limiting LHGRFACp transient analysis results for each EOOS scenario used to develop the operating limits for NSS, ESS, and TSSS insertion times, respectively.

5.3.1 **FHOOS**

The FHOOS scenario assumes a feedwater temperature reduction of 110.3°F at rated power and steam flow. The effect of the reduced feedwater temperature is an increase in the core inlet subcooling which can change the axial power shape and core void fraction. In addition, the steam flow for a given power level decreases since more power is required to increase the enthalpy of the coolant to saturated conditions. The consequences of the FWCF event are potentially more severe as a result of the increase in core inlet subcooling during the overcooling phase of the event. While the decrease in steam flow tends to make the LRNB event less severe, the TCV initial position is further closed which tends to make the event more severe, especially at higher power levels. FWCF events were analyzed to ensure that appropriate FHOOS operating limits are established. Operation with FHOOS or the related FFTR scenario is not allowed in the MELLLA+ region.

5.3.2 TBVOOS

For this EOOS scenario, operation with TBVOOS means that the fast opening capability of three or more of the turbine bypass valves cannot be assured, thereby reducing the pressure relief capacity during fast pressurization transients. While the base case LRNB and TTNB events are analyzed assuming the turbine bypass valves out-of-service, operation with TBVOOS has an adverse effect on the FWCF event. Analyses of the FWCF event with TBVOOS were performed to establish the TBVOOS operating limits.

5.3.3 Combined FHOOS and TBVOOS

FWCF analyses with both FHOOS and TBVOOS were performed. Operating limits for this combined EOOS scenario were established using these FWCF results. This scenario is not allowed in the MELLLA+ region.

5.3.4 One SRVOOS

As noted earlier, all pressurization transient analyses were performed with one of the lowest setpoint SRVs assumed inoperable. Therefore, the base case operating limits support operation with one SRVOOS. The EOOS operating limits also support operation with one SRVOOS.

5.3.5 One MSIVOOS

Operation with one MSIVOOS is supported for operation less than 70% of rated power. At these reduced power levels, the flow through any one steam line will not be greater than the flow at rated power when all MSIVs are available. Since all four turbine control valves are available, adequate pressure control can be maintained. The main difference in operation with one MSIVOOS is that the steam line pressure drop between the steam dome and the turbine valves is higher than if all MSIVs are available. Since low steam line pressure drop is limiting for pressurization transients, the results of the pressurization events with all MSIVs in service bound the results with one MSIVOOS. In addition, operation with one MSIVOOS has no impact on the other nonpressurization events evaluated to establish power-dependent operating limits. Therefore, the power-dependent operating limits applicable to base case operation with all

MSIVs in service remain applicable for operation with one MSIVOOS for power levels less than or equal to 70% of rated. As noted earlier, slow flow runup analyses were performed to support operation with one MSIVOOS.

5.3.6 Single-Loop Operation

Operation in SLO is only supported up to a maximum core flow of 45 Mlbm/hr which corresponds to a maximum power level of 71.1% of rated at the MELLLA boundary. In SLO, the two-loop operation limiting ∆MCPRs and LHGRFAC multipliers remain applicable. The only impacts on the MCPR, LHGR, and MAPLHGR limits for SLO are an increase of 0.01 in the SLMCPR as discussed in Section 4.2, and the application of an SLO MAPLHGR multiplier discussed in Section 8.3. The net result is a 0.01 increase in the base case $MCPR_p$ limits and a decrease in the MAPLHGR limit. The same situation is true for the EOOS scenarios. Adding 0.01 to the corresponding two-loop operation EOOS $MCPR_p$ limits results in SLO $MCPR_p$ limits for the EOOS conditions. The TLO EOOS LHGRFAC multipliers remain applicable in SLO. This scenario is not allowed in the MELLLA+ region.

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 36,653 MWd/MTU is given in Table 5.13. Cycle 25 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 5.13 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 5.13 was calculated using the MICROBURN-B2 code. Compliance analyses must also be performed using MICROBURN-B2. Note that the power profile comparison should be done without incorporating instrument updates to the axial profile because the updated power is not used in the core monitoring system to accumulate assembly burnups.

Table 5.1 Exposure Basis for Brunswick Unit 2 Cycle 25 Transient Analysis

Cycle Exposure at End of Interval (MWd/MTU)	Core Average Exposure (MWd/MTU)*	Comments
0	18,021	Beginning of cycle
16,000	34,021	Break point for exposure-dependent $MCPR_p$ limits (NEOC)
18,632	36,653	Design basis rod patterns to EOFP + 15 EFPD (EOCLB)
20,668	38,689	Maximum licensing core exposure – including FFTR /Coastdown

* Note that the limits presented in Tables 8.1 – 8.9 and Tables 8.13 – 8.18 are based on core average exposure.

**Table 5.2 Scram Speed
Insertion Times**

Control Rod Position (notch)	TSSS Time (sec)	ESS Time (sec)	NSS Time (sec)
48 (*full-out*)	0.000	0.000	0.000
48	0.200	0.200	0.200
46	0.440	0.326	0.305
36	1.080	0.846	0.816
26	1.830	1.419	1.362
6	3.350	2.602	2.499
0 (*full-in*)	3.806	2.957	2.840

Table 5.3 EOCLB Base Case Limiting Transient Event NSS Insertion Time

Power	ATRIUM 10XM ΔMCPR	Limiting Event	ATRIUM 11 ΔMCPR	Limiting Event
100	0.25	LRNB	0.28	TTNB
90	0.26	LRNB	0.28	LRNB
80	0.28	LRNB	0.31	LRNB
70	0.28	LRNB	0.32	LRNB
60	0.31	LRNB	0.36	LRNB
50	0.34	LRNB	0.39	LRNB
50 at > 65%F PLU inoperable	0.75	LRNB	0.74	LRNB
50 at ≤ 65%F PLU inoperable	0.56	LRNB	0.56	LRNB
40 at > 65%F PLU inoperable	0.78	LRNB	0.77	LRNB
40 at ≤ 65%F PLU inoperable	0.66	LRNB	0.62	LRNB
30 at > 65%F PLU inoperable	0.90	LRNB	0.92	LRNB
30 at ≤ 65%F PLU inoperable	0.79	LRNB	0.73	LRNB
26 at > 65%F PLU inoperable	1.05	LRNB	1.06	LRNB
26 at ≤ 65%F PLU inoperable	0.86	LRNB	0.78	LRNB
26 at > 65%F below P_{bypass}	1.05	LRNB	1.07	LRNB
26 at ≤ 65%F below P_{bypass}	0.90	TTNB	0.86	TTNB
23 at > 65%F below P_{bypass}	1.06	TTNB	1.10	TTNB
23 at ≤ 65%F below P_{bypass}	0.92	TTNB	0.86	LRNB

Table 5.4 EOCLB Base Case Limiting Transient Event ESS Insertion Time

Power	ATRIUM 10XM ΔMCPR	Limiting Event	ATRIUM 11 ΔMCPR	Limiting Event
100	0.25	LRNB	0.28	LRNB/TTNB
90	0.26	LRNB	0.28	LRNB
80	0.28	LRNB	0.31	LRNB
70	0.28	LRNB	0.32	LRNB
60	0.31	LRNB	0.36	LRNB
50	0.34	LRNB	0.39	LRNB
50 at > 65%F PLU inoperable	0.75	LRNB	0.74	LRNB
50 at ≤ 65%F PLU inoperable	0.56	LRNB	0.56	LRNB
40 at > 65%F PLU inoperable	0.78	LRNB	0.77	LRNB
40 at ≤ 65%F PLU inoperable	0.66	LRNB	0.62	LRNB
30 at > 65%F PLU inoperable	0.90	LRNB	0.92	LRNB
30 at ≤ 65%F PLU inoperable	0.79	LRNB	0.73	LRNB
26 at > 65%F PLU inoperable	1.05	LRNB	1.06	LRNB
26 at ≤ 65%F PLU inoperable	0.86	LRNB	0.78	LRNB
26 at > 65%F below P_{bypass}	1.05	LRNB	1.07	LRNB
26 at ≤ 65%F below P_{bypass}	0.90	TTNB	0.86	TTNB
23 at > 65%F below P_{bypass}	1.06	TTNB	1.10	TTNB
23 at ≤ 65%F below P_{bypass}	0.92	TTNB	0.86	LRNB

Table 5.5 EOCLB Base Case Limiting Transient Event TSSS Insertion Time

Power	ATRIUM 10XM ΔMCPR	Limiting Event	ATRIUM 11 ΔMCPR	Limiting Event
100	0.31	LRNB	0.35	LRNB
90	0.30	LRNB	0.33	LRNB
80	0.31	LRNB	0.34	LRNB
70	0.30	LRNB	0.35	LRNB
60	0.34	LRNB	0.40	LRNB
50	0.45	LRNB	0.50	LRNB
50 at > 65%F PLU inoperable	0.75	LRNB	0.74	LRNB
50 at ≤ 65%F PLU inoperable	0.56	LRNB	0.56	LRNB
40 at > 65%F PLU inoperable	0.78	LRNB	0.77	LRNB
40 at ≤ 65%F PLU inoperable	0.66	LRNB	0.62	LRNB
30 at > 65%F PLU inoperable	0.90	LRNB	0.92	LRNB
30 at ≤ 65%F PLU inoperable	0.79	LRNB	0.73	LRNB
26 at > 65%F PLU inoperable	1.05	LRNB	1.06	LRNB
26 at ≤ 65%F PLU inoperable	0.86	LRNB	0.78	LRNB
26 at > 65%F below P_{bypass}	1.05	LRNB	1.07	LRNB
26 at ≤ 65%F below P_{bypass}	0.90	TTNB	0.86	TTNB
23 at > 65%F below P_{bypass}	1.06	TTNB	1.10	TTNB
23 at ≤ 65%F below P_{bypass}	0.92	TTNB	0.86	LRNB

Table 5.6 Loss of Feedwater Heating Transient Analysis Results

Power (% rated)	ATRIUM 10XM and ATRIUM 11 ∆CPR
100	0.14
90	0.15
80	0.16
70	0.17
60	0.18
50	0.20
40	0.23
30	0.28
23	0.34

Table 5.7 Control Rod Withdrawal Error ∆CPR Results

Analytical RBM Setpoint (without filter) (%)	ATRIUM 10XM ΔCPR	ATRIUM 11 ΔCPR
108	0.20	0.17
111	0.25	0.22
114	0.27	0.25
117	0.31	0.27

Table 5.8 RBM Operability Requirements

Thermal Power (% rated)	Applicable ATRIUM 10XM OLMCPR	Applicable ATRIUM 11 OLMCPR
≥ 29% and < 90%	1.71 TLO	1.60 TLO
	1.74 SLO	1.63 SLO
≥ 90%	1.41 TLO	1.40 TLO

Table 5.9 Flow-Dependent MCPR Results

Core Flow (% rated)	ATRIUM 10XM Limiting MCPR MSIVIS	ATRIUM 10XM Limiting MCPR MSIVOOS	ATRIUM 11 Limiting MCPR MSIVIS	ATRIUM 11 Limiting MCPR MSIVOOS
31	1.40	1.54	1.36	1.48
40	1.38	1.50	1.32	1.42
50	1.39	1.49	1.32	1.40
60	1.39	1.47	1.30	1.36
70	1.32	1.38	1.27	1.33
80	1.26	1.30	1.24	1.27
90	1.22	1.25	1.19	1.21
100	1.17	1.18	1.14	1.15
107	1.11	1.11	1.08	1.08

**Table 5.10 EOCLB LHGRFACp Transient Results
NSS Insertion Time**

Power	Base Case	FHOOS	TBVOOS	FHOOS/ TBVOOS
		ATRIUM 11 Fuel		
100	1.00	1.00	1.00	1.00
90	1.00	1.00	1.00	1.00
50	1.00	0.96	0.97	0.91
50 at > 65%F PLU inoperable	0.86	0.86	0.86	0.86
50 at ≤ 65%F PLU inoperable	0.95	0.95	0.95	0.95
26 at > 65%F PLU inoperable	0.68	0.68	0.68	0.68
26 at ≤ 65%F PLU inoperable	0.80	0.80	0.80	0.80
26 at > 65%F below P_{bypass}	0.68	0.61	0.41	0.38
26 at ≤ 65%F below P_{bypass}	0.80	0.75	0.51	0.48
23 at > 65%F below P_{bypass}	0.64	0.59	0.38	0.35
23 at ≤ 65%F below P_{bypass}	0.78	0.71	0.46	0.43
		ATRIUM 10XM Fuel		
100	1.00	1.00	1.00	1.00
90	1.00	1.00	1.00	1.00
50	1.00	1.00	1.00	0.97
50 at > 65%F PLU inoperable	0.93	0.93	0.93	0.93
50 at ≤ 65%F PLU inoperable	1.00	1.00	1.00	1.00
26 at > 65%F PLU inoperable	0.75	0.75	0.75	0.75
26 at ≤ 65%F PLU inoperable	0.86	0.86	0.86	0.86
26 at > 65%F below P_{bypass}	0.75	0.65	0.45	0.42
26 at ≤ 65%F below P_{bypass}	0.84	0.78	0.56	0.52
23 at > 65%F below P_{bypass}	0.71	0.63	0.41	0.38
23 at ≤ 65%F below P_{bypass}	0.83	0.77	0.50	0.47

Table 5.11 EOCLB LHGRFACp Transient Results
ESS Insertion Time

Power	Base Case	FHOOS	TBVOOS	FHOOS/ TBVOOS
ATRIUM 11 Fuel				
100	1.00	1.00	1.00	1.00
90	1.00	1.00	1.00	1.00
50	1.00	0.96	0.97	0.91
50 at > 65%F PLU inoperable	0.86	0.86	0.86	0.86
50 at ≤ 65%F PLU inoperable	0.95	0.95	0.95	0.95
26 at > 65%F PLU inoperable	0.68	0.68	0.68	0.68
26 at ≤ 65%F PLU inoperable	0.80	0.80	0.80	0.80
26 at > 65%F below P_{bypass}	0.68	0.61	0.41	0.38
26 at ≤ 65%F below P_{bypass}	0.80	0.75	0.51	0.48
23 at > 65%F below P_{bypass}	0.64	0.59	0.38	0.35
23 at ≤ 65%F below P_{bypass}	0.78	0.71	0.46	0.43
ATRIUM 10XM Fuel				
100	1.00	1.00	1.00	1.00
90	1.00	1.00	1.00	1.00
50	1.00	1.00	1.00	0.97
50 at > 65%F PLU inoperable	0.93	0.93	0.93	0.93
50 at ≤ 65%F PLU inoperable	1.00	1.00	1.00	1.00
26 at > 65%F PLU inoperable	0.75	0.75	0.75	0.75
26 at ≤ 65%F PLU inoperable	0.86	0.86	0.86	0.86
26 at > 65%F below P_{bypass}	0.75	0.65	0.45	0.42
26 at ≤ 65%F below P_{bypass}	0.84	0.78	0.56	0.52
23 at > 65%F below P_{bypass}	0.71	0.63	0.41	0.38
23 at ≤ 65%F below P_{bypass}	0.83	0.77	0.50	0.47

Table 5.12 EOCLB LHGRFACp Transient Results
TSSS Insertion Time

Power	Base Case	FHOOS	TBVOOS	FHOOS/ TBVOOS
		ATRIUM 11 Fuel		
100	1.00	1.00	1.00	0.97
90	-	-	-	-
50	1.00	0.95	0.92	0.87
50 at > 65%F PLU inoperable	0.86	0.86	0.86	0.86
50 at ≤ 65%F PLU inoperable	0.95	0.95	0.95	0.95
26 at > 65%F PLU inoperable	0.68	0.68	0.68	0.68
26 at ≤ 65%F PLU inoperable	0.80	0.80	0.80	0.80
26 at > 65%F below P_{bypass}	0.68	0.61	0.41	0.38
26 at ≤ 65%F below P_{bypass}	0.80	0.75	0.51	0.48
23 at > 65%F below P_{bypass}	0.64	0.59	0.38	0.35
23 at ≤ 65%F below P_{bypass}	0.78	0.71	0.46	0.43
		ATRIUM 10XM Fuel		
100	1.00	1.00	1.00	1.00
90	1.00	1.00	1.00	1.00
50	1.00	1.00	0.98	0.93
50 at > 65%F PLU inoperable	0.93	0.93	0.93	0.93
50 at ≤ 65%F PLU inoperable	1.00	1.00	1.00	1.00
26 at > 65%F PLU inoperable	0.75	0.75	0.75	0.75
26 at ≤ 65%F PLU inoperable	0.86	0.86	0.86	0.86
26 at > 65%F below P_{bypass}	0.75	0.65	0.45	0.42
26 at ≤ 65%F below P_{bypass}	0.84	0.78	0.56	0.52
23 at > 65%F below P_{bypass}	0.71	0.63	0.41	0.38
23 at ≤ 65%F below P_{bypass}	0.83	0.77	0.50	0.47

Table 5.13 Licensing Basis Core Average Axial Power Profile

State Conditions for Power Shape Evaluation	
Power, MWt	2,923.0
MICROBURN-B2 pressure, psia	1,044.8
Inlet subcooling, Btu/lbm	20.5
Flow, Mlb/hr	79.7
Control state	ARO
Core average exposure (EOCLB), MWd/MTU	36,653

Licensing Axial Power Profile (Normalized)

	Node	Power
Top	25	0.266
	24	0.587
	23	0.965
	22	1.155
	21	1.261
	20	1.347
	19	1.390
	18	1.421
	17	1.418
	16	1.387
	15	1.379
	14	1.325
	13	1.340
	12	1.288
	11	1.205
	10	1.157
	9	1.085
	8	0.993
	7	0.897
	6	0.803
	5	0.701
	4	0.596
	3	0.510
	2	0.403
Bottom	1	0.119

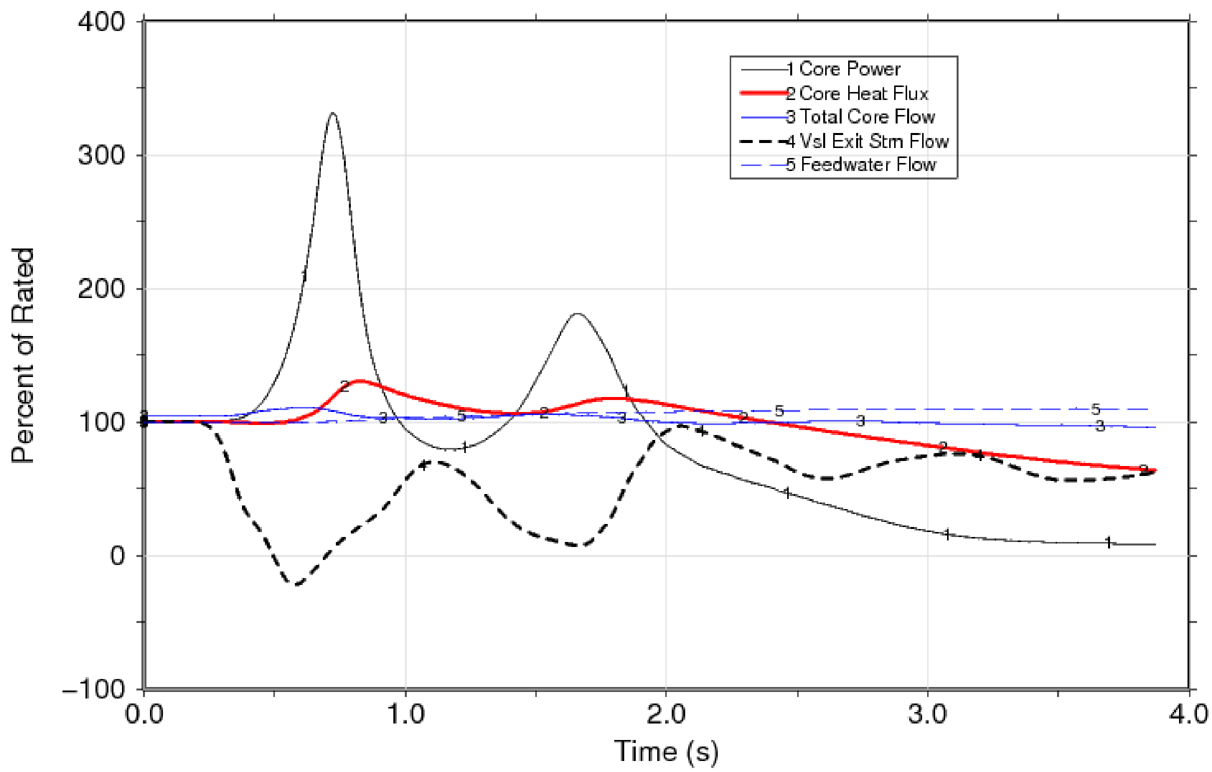

Figure 5.1 EOCLB LRNB at 100P/104.5F – TSSS Key Parameters

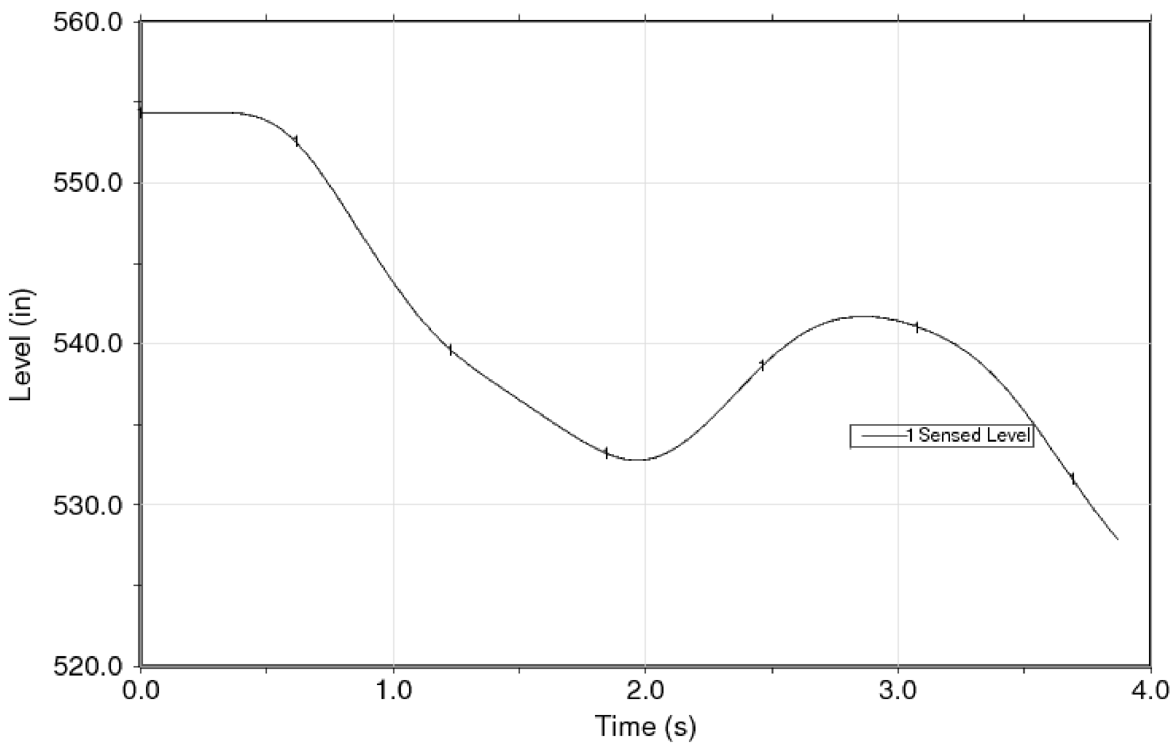

Figure 5.2 EOCLB LRNB at 100P/104.5F – TSSS Sensed Water Level

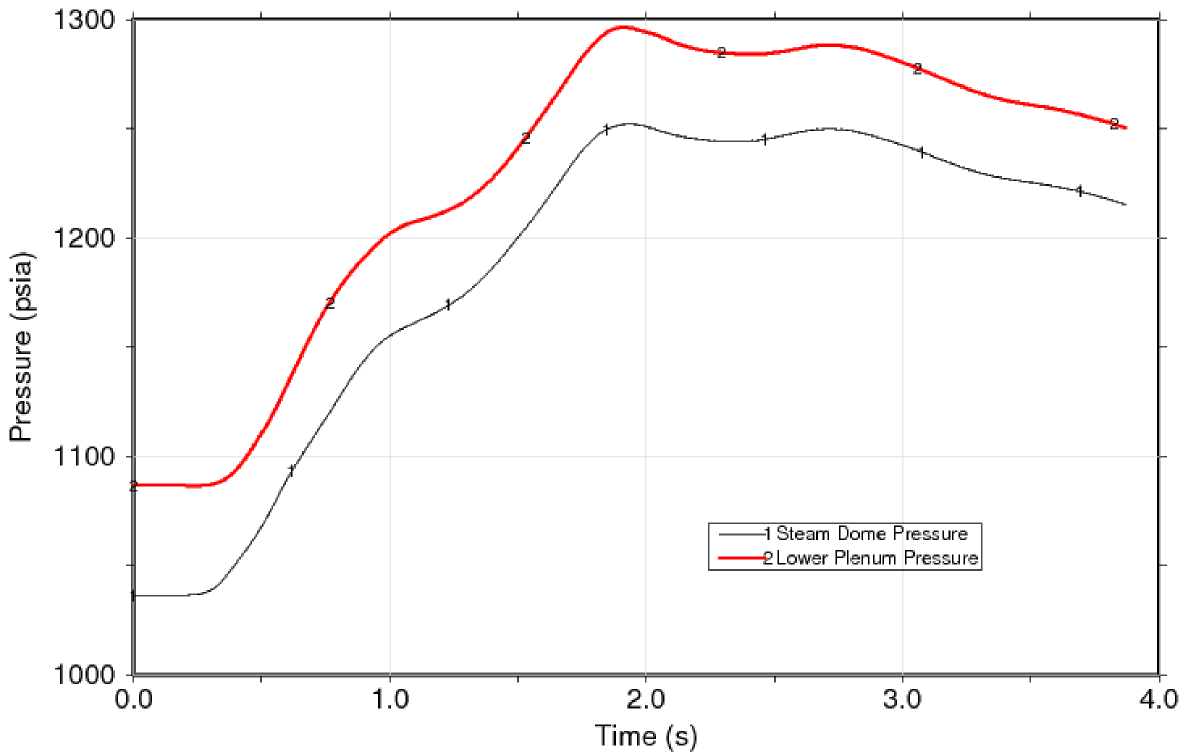

Figure 5.3 EOCLB LRNB at 100P/104.5F – TSSS
Vessel Pressures

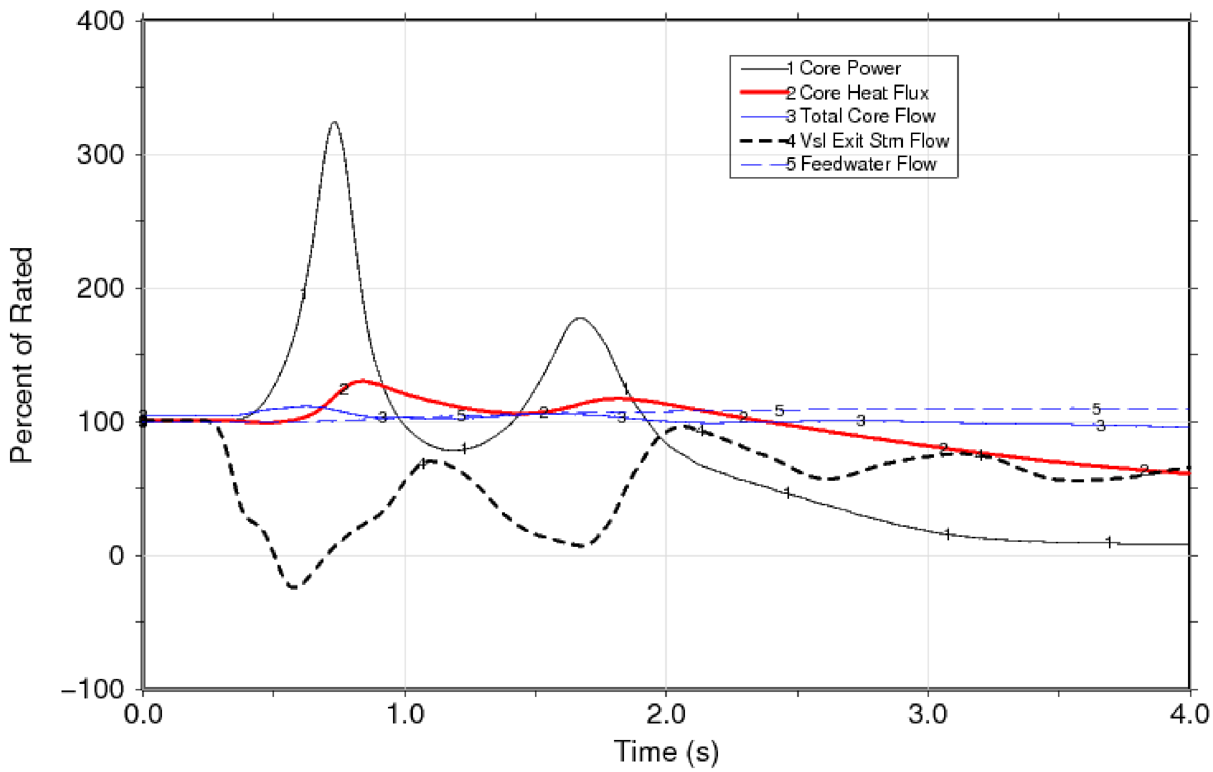

Figure 5.4 EOCLB TTNB at 100P/104.5F – TSSS Key Parameters

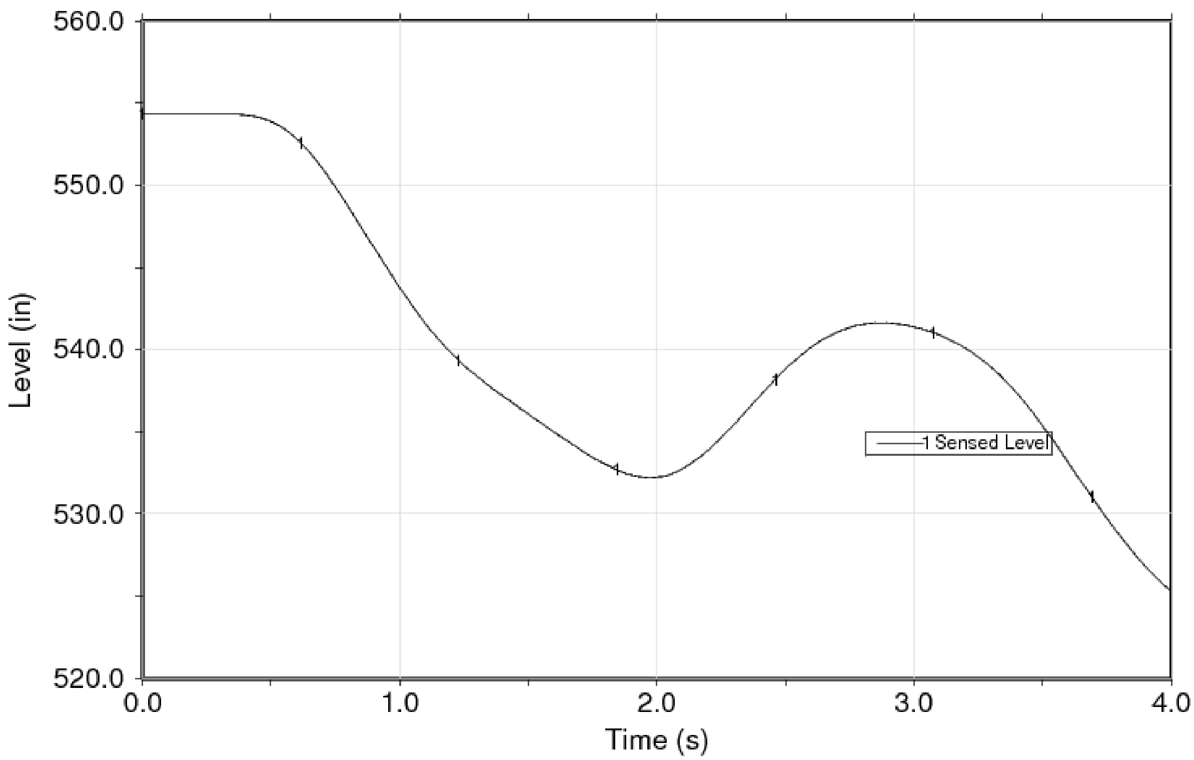

**Figure 5.5 EOCLB TTNB at 100P/104.5F – TSSS
Sensed Water Level**

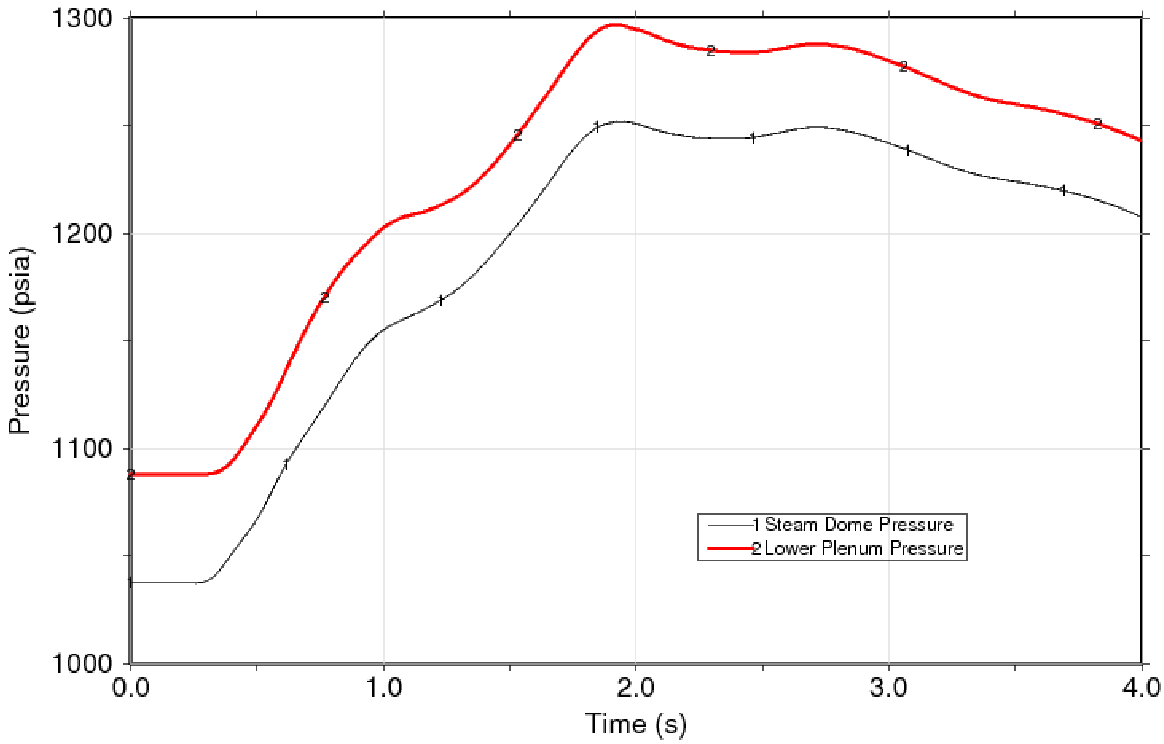

Figure 5.6 EOCLB TTNB at 100P/104.5F – TSSS Vessel Pressures

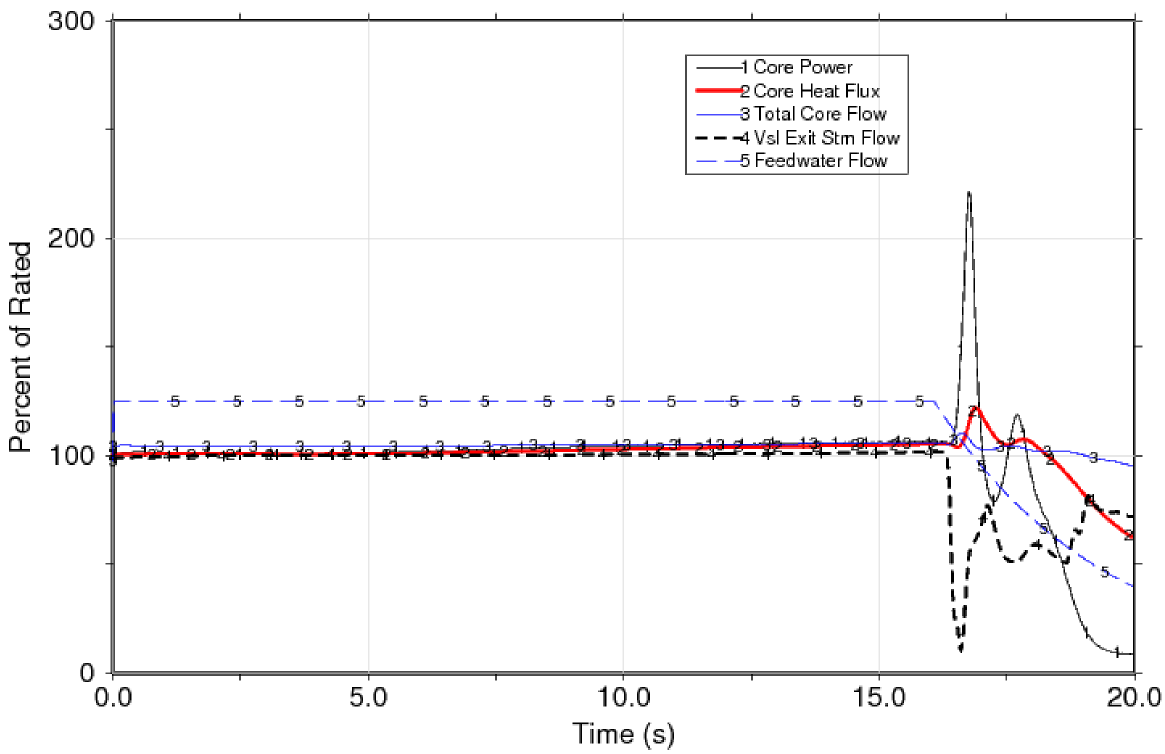

Figure 5.7 EOCLB FWCF at 100P/104.5F – TSSS Key Parameters

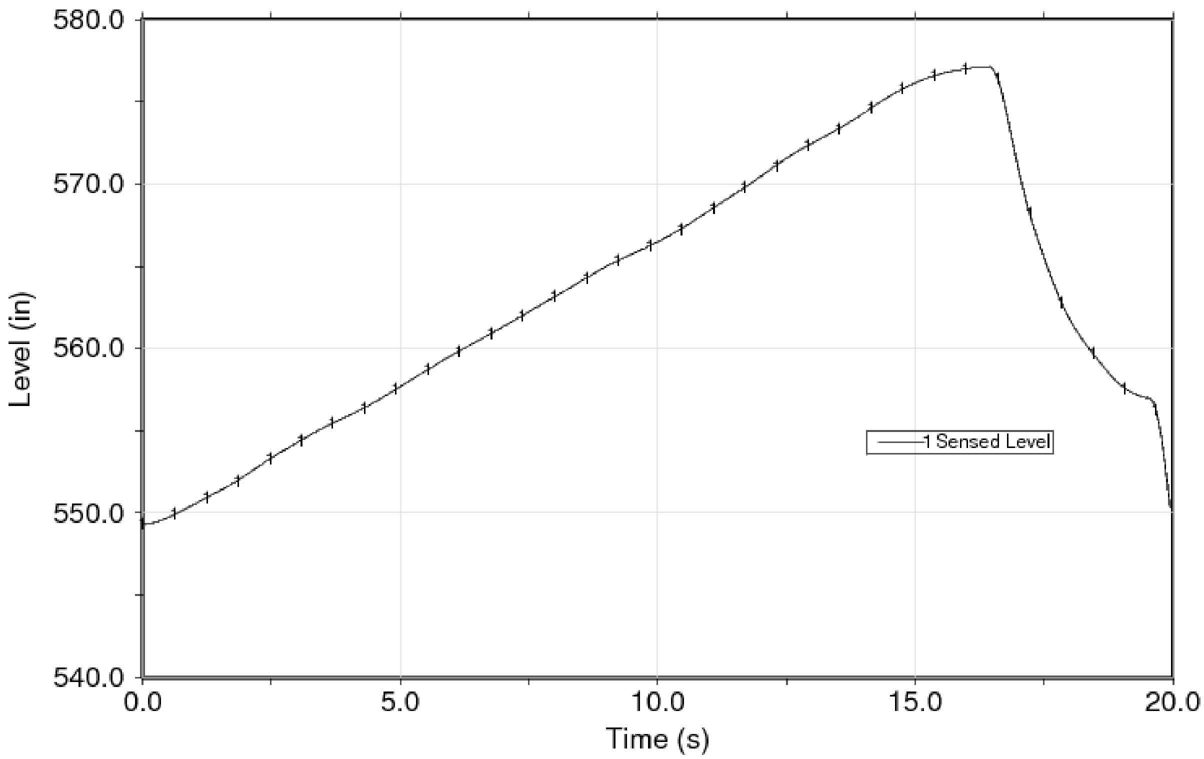

Figure 5.8 EOCLB FWCF at 100P/104.5F – TSSS
Sensed Water Level

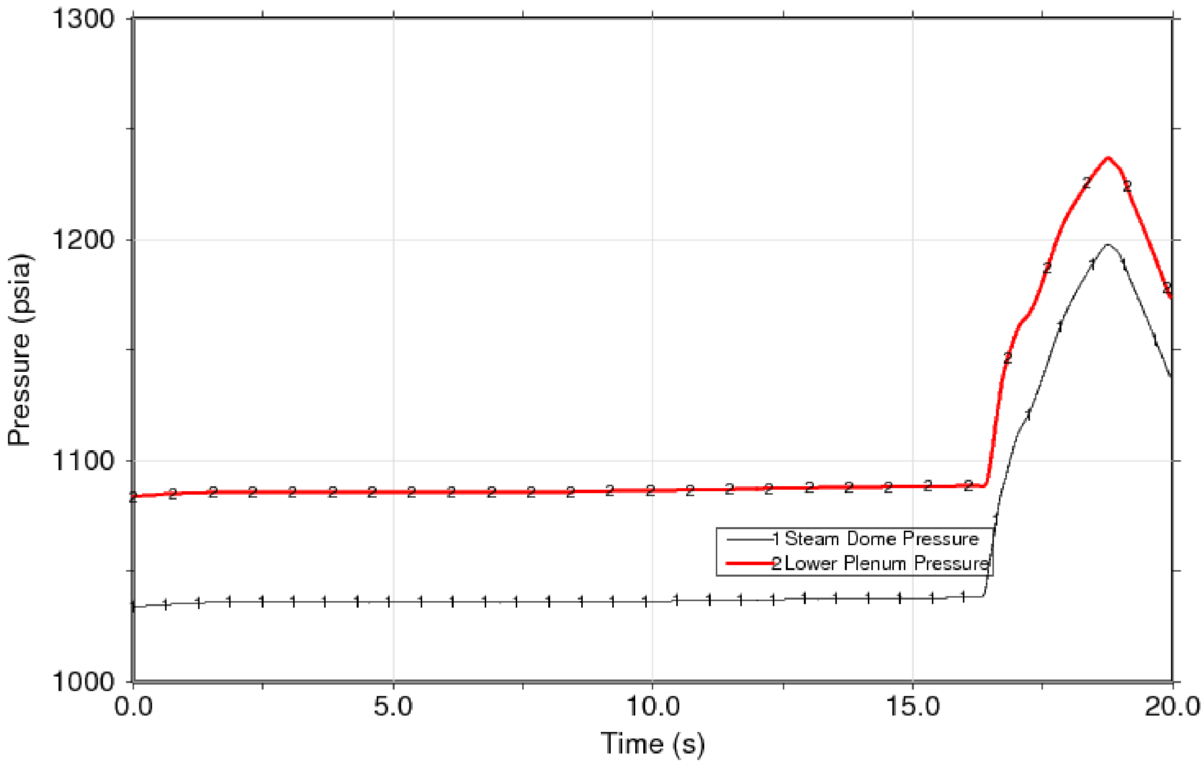

**Figure 5.9 EOCLB FWCF at 100P/104.5F – TSSS
Vessel Pressures**

6.0 POSTULATED ACCIDENTS

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

The results of the ATRIUM 10XM LOCA analysis are presented in References 24 and 25 and provide a PCT of 1925°F, as supplemented by Reference 27. The peak local metal water reaction is 1.23% and the core wide metal water reaction is < 0.56%. The SLO MAPLHGR multiplier is 0.80; however SLO is not allowed when operating in the MELLLA+ domain. The cycle-specific OLMCPRs and off-rated flow dependent LHGR setdown bounds those assumed in References 24 and 25.

A LOCA evaluation was performed for the ATRIUM 11 fuel for MELLLA+ operation and the results are presented in Reference 26 and provide a PCT of 1882°F, as supplemented by Reference 40. The peak local metal water reaction is 4.75% and the core wide metal water reaction is 0.41%. The ATRIUM 11 SLO MAPLHGR multiplier is 0.85. The cycle-specific OLMCPRs and off-rated flow dependent LHGR setdown bounds those assumed in Reference 26. The ATRIUM 11 LOCA analyses are based on the **[**

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The Brunswick LOCA radiological analysis implementing the alternative source term methodology was performed in consideration of ATRIUM 10XM and ATRIUM 11 fuel in the core inventory source terms. Duke Energy has evaluated the radiological consequences of a LOCA and determined ATRIUM 10XM and ATRIUM 11 fuel meets the applicable acceptance criteria for Brunswick Unit 2 Cycle 25.

6.2 *Control Rod Drop Accident (CRDA)*

Brunswick Unit 2 uses a bank position withdrawal sequence (BPWS) including reduced notch worth rod pull to limit high worth control rod movements. The CRDA evaluation is performed for both A and B sequence startups consistent with the withdrawal sequence specified by Duke Energy (Reference 39 or equivalent) with additional cycle-specific group banking requirements listed below*.

* Note that the constraints on startups in B-sequence may be satisfied with the 'B2X' withdrawal sequence from the existing Duke Energy procedure in Reference 39.

During any startup after a Cycle 25 core average exposure of 35,947 MWd/MTU:

1. B-sequence group 2 dropped as the second group must be banked at position **08** or **10** before withdrawing further.
2. B-sequence group 3 *or* 4 dropped as the third group must be banked at position **06** before withdrawing further.

Framatome's AURORA-B CRDA methodology (Reference 32) is used. Applicability of this methodology for the Brunswick plant is demonstrated in Reference 33. The analysis utilized the current Brunswick failure criteria (including DG-1327 Reference 34). Results demonstrate that with the additional restrictions listed above, core coolability is maintained with total fuel enthalpy remaining below 230 cal/g and no fuel melting. The radiological consequences are shown to be bounded by the Brunswick CRDA AST analysis.

The following table identifies the limiting rod drop with the actual number of rod failures and the number of rod failures scaled up to account for the revised release fractions of DG-1327* compared to those of RG 1.183. Duke Energy has determined the radiological release assumed in the current Brunswick CRDA AST analysis bounds 955 rod failures for core source terms based on ATRIUM 10XM fuel and 1129 rod failures for core source terms based on ATRIUM 11 (Reference 35).

					ATRIUM 10XM		ATRIUM 11		
Sequence	Max Prompt Enthalpy Increase (cal / g)	Max Total Enthalpy (cal / g)	Fuel Melting	Bundles with Failures	Actual Rod Failures†	BRK FSAR Equivalent Failures‡	Actual Rod Failures	BRK FSAR Equivalent Failures	Fraction of Allowed Rod Failures
B1234	191.94	213.37	no	4	5	7	106	155	0.15§

* Results are provided using the criteria specified in the Reference 34 version of DG-1327 which is consistent with the criteria previously used in ANP-3714P (Reference 33).

† The actual numbers of rod failures are the total unique rod failures from the PCMI, high temperature, and fuel melt criteria.

‡ The FSAR equivalent rod failures account for the difference in release fraction between those used in the Brunswick plant licensing based on RG 1.183 and a conservative scaling based on revised release fractions proposed in DG-1327. These scaled values account for revision in calculation method for transient fission gas release fraction (Reference 35).

§ Equivalent fuel rod failures from each fuel type are counted toward their number of allowed failures individually and those fractions are summed to give an effective total fraction of failed fuel rods.

6.3 *Fuel and Equipment Handling Accident*

Duke Energy has determined the radiological release assumed in the current fuel handling accident (FHA) analysis implementing the AST methodology bounds 161 rod failures for core source terms based on ATRIUM 10XM fuel. Framatome has performed an analysis that shows that the number of failed fuel rods due to a fuel handling accident involving the ATRIUM 10XM fuel is 161. These results are consistent with the number of failed rods supported by the current Brunswick AST analysis.

Framatome has also performed an analysis that shows that the number of failed fuel rods due to a fuel handling accident involving the ATRIUM 11 fuel does not exceed 194. These results are consistent with the number of failed rods supported by the current Brunswick AST analysis.

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 14, the fuel loading error is characterized as an infrequent event. The acceptance criteria are that the offsite dose consequences due to the event shall not exceed a small fraction of the 10 CFR 50.67 limits.

6.4.1 *Mislocated Fuel Bundle*

Framatome has performed a fuel mislocation error analysis for Brunswick Unit 2 Cycle 25. This analysis evaluated the impact of a mislocated assembly against potential fuel rod failure mechanisms due to increased LHGR and reduced CPR. Based on this analysis, 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 approached the fuel centerline melt or 1% strain limits, and less than 0.1% of the fuel rods are expected to experience boiling transition which could result in a dryout induced failure.

6.4.2 *Misoriented Fuel Bundle*

Framatome has performed a fuel assembly misorientation analysis for all fuel assemblies in Brunswick Unit 2 Cycle 25 (monitored with the ACE critical power correlation). The analysis was performed assuming that the limiting assembly was loaded in the worst orientation (rotated 180°) and depleted through the cycle without operator interaction. The analysis demonstrates that the small fraction of 10 CFR 50.67 offsite dose criteria is conservatively satisfied. A dose consequence evaluation is not necessary since no rod approached 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 that the safety/relief valves at Brunswick Unit 2 have sufficient capacity and performance to prevent the reactor vessel pressure from reaching the safety limit of 110% of the design pressure.

For Brunswick Unit 2 Cycle 25, a set of MSIV closure runs were first performed for 102% power and 104.5% flow and 85% flow at the highest Cycle 25 exposure where rated power operation can be attained. The MSIV closure event is similar to the other steam line valve closure events in that the valve closure results in a rapid pressurization of the core. The increase in pressure causes a decrease in void which in turn causes a rapid increase in power. The turbine bypass valves do not impact the system response and are not modeled in the analysis. [

] The following assumptions were made in the analysis:

- The most critical active component (direct scram on valve position) was assumed to fail. However, scram on high neutron flux and high dome pressure is available.
- The plant configuration analyzed assumed degraded lift setpoints of the limiting bank of SRVs (Reference 4, Item V.A). The SRV degradation scheme is based on actual plant performance using a 95/95 approach with the two valves at 6% drift replaced with 7% drift and the one valve at 8% drift replaced with 10% drift. This bounds the 3% Technical Specifications requirement. In addition, one of the lowest setpoint SRVs is assumed inoperable.
- TSSS insertion times were used.
- The initial dome pressure was set at the maximum allowed by the Technical Specifications, 1059.7 psia (1045 psig).
- A fast MSIV closure time of 2.7 seconds was used.

Results of the limiting MSIV closure overpressurization analysis are presented in Table 7.1. Figures 7.1 – 7.4 show the response of various reactor plant parameters during the MSIV closure event. The maximum pressure of 1350 psig occurs in the lower plenum. The maximum dome pressure for the same event is 1309 psig. The results demonstrate that the maximum vessel pressure limit of 1375 psig and dome pressure limit of 1325 psig are not exceeded.

7.2 *ATWS Event Evaluation*

7.2.1 ATWS Overpressurization Analysis

This section describes the analyses performed to demonstrate that the peak vessel pressure for the limiting ATWS event is less than the ASME Service Level C limit of 120% of the design pressure (1500 psig). The ATWS overpressurization analyses were performed at 100% power at 85% and 104.5% flow. The MSIV closure and pressure regulator failure open (PRFO) events were evaluated. Failure of the pressure regulator in the open position causes the turbine control and turbine bypass valves to open such that steam flow increases until the maximum combined steam flow limit is attained. The system pressure decreases until the low pressure setpoint is reached, resulting in the closure of the MSIVs. The resulting pressurization wave causes a decrease in core voids and an increase in core pressure thereby increasing the core power. For the MSIV closure event, the event is initiated by a fast closure of the MSIVs. This results in a pressurization wave that causes a decrease in core voids which results in an increase in core power and pressure.

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The following assumptions were made in the analyses:

- The analytical limit ATWS-RPT setpoint and function were assumed.
- The plant configuration analyzed assumed degraded lift setpoints of the limiting bank of SRVs (Reference 4, Item V.B). The SRV degradation scheme is based on actual plant performance using a 95/95 approach with the two valves at 6% drift replaced with 7% drift and the one valve at 8% drift replaced with 10% drift. This bounds the 3% Technical Specifications requirement. To support operation with one SRVOOS, the plant configuration analyzed assumed that one of the lowest setpoint SRVs was inoperable.
- All scram functions were disabled.
- The initial dome pressure was set to the nominal pressure with a -10 psi uncertainty (1035 psia).
- The MSIV closure is based on a nominal closure time of 4.0 seconds for both events.

Results of ATWS overpressurization analyses are presented in Table 7.2. Figures 7.5 – 7.8 show the response of various reactor plant parameters during the limiting MSIV closure event, the event which results in the maximum vessel pressure. The maximum lower plenum pressure is 1451 psig and the maximum dome pressure is 1433 psig. The results demonstrate that the ATWS maximum vessel pressure limit of 1500 psig is not exceeded.

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. [

] A review of the current licensing basis for Brunswick ATWS containment, which is a full core of ATRIUM 10XM fuel, shows that peak suppression pool temperature for MELLLA+ was 174 °F and the peak containment pressure was 8.4 psig, Section 9.3.1 of Reference 18.

For Brunswick Unit 1 Cycle 23 (Reference 38) an evaluation was performed that concluded the introduction of ATRIUM 11 fuel will not significantly impact the long term ATWS response (suppression pool temperature and containment pressure) and the current analysis of record remains applicable. This conclusion remains applicable for the current licensing reload.

Relative to the 10 CFR 50.46 acceptance criteria (i.e., PCT and cladding oxidation), the consequences of an ATWS event are bound by those of the limiting LOCA event.

7.2.3 ATWS with Core Instability

The ATWS with core instability (ATWS-I) event was originally approved for ATRIUM 10XM in MELLLA+ at Brunswick in Reference 18. For ATRIUM 11 fuel, the Brunswick plant specific ATWS-I methodology, Reference 31 was used. The Brunswick ATRIUM 11 results given in Appendix F of Reference 31 demonstrate that the acceptance criteria are met.

7.3 *Standby Liquid Control System*

In the event that the control rod scram function becomes incapable of rendering the core in a shutdown state, the standby liquid control (SLC) system is required to be capable of bringing the reactor from full power to a cold shutdown condition at any time in the core life. The Brunswick Unit 2 SLC system is required to be able to inject 720 ppm natural boron equivalent at 68°F into the reactor coolant (including a 25% allowance for imperfect mixing, leakage, and volume of other piping connected to the reactor). An analysis that demonstrates that the SLC system meets the required shutdown capability for Cycle 25 has been performed. The analysis was performed to support a coolant temperature of 360°F with a boron concentration equivalent to 720 ppm at 70°F. The temperature of 360°F corresponds to the low pressure permissive for the RHR shutdown cooling suction valves, and represents the maximum reactivity condition with soluble boron in the coolant. The Reference 3 analysis shows the core to be subcritical throughout the cycle by at least 1.27% Δk.

7.4 *Fuel Criticality*

The new fuel storage vault criticality analysis for ATRIUM 11 fuel is presented in Reference 28. The spent fuel pool criticality analysis for ATRIUM 11 fuel is presented in Reference 29. The ATRIUM 11 fuel assemblies identified for loading in Cycle 25 meet both the new and spent fuel storage requirements (Reference 3).

7.5 *Strongest Rod Out Shutdown Margin*

As shown in Reference 3, the BRK2-25 core has a minimum strongest rod out shutdown margin of 1.14 %Δk. This value is produced at the beginning of the cycle at the minimum coolant temperature condition (68°F). This value assumes that BRK2-24 ended operation at the lowest allowable exposure.

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/104.5F)	184	132	1350	1309

* The SRV degradation scheme is based on actual plant performance using a 95/95 approach with the two valves at 6% drift replaced with 7% drift and the one valve at 8% drift replaced with 10% drift.

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)	223	148	1451	1433

* The SRV degradation scheme is based on actual plant performance using a 95/95 approach with the two valves at 6% drift replaced with 7% drift and the one valve at 8% drift replaced with 10% drift.

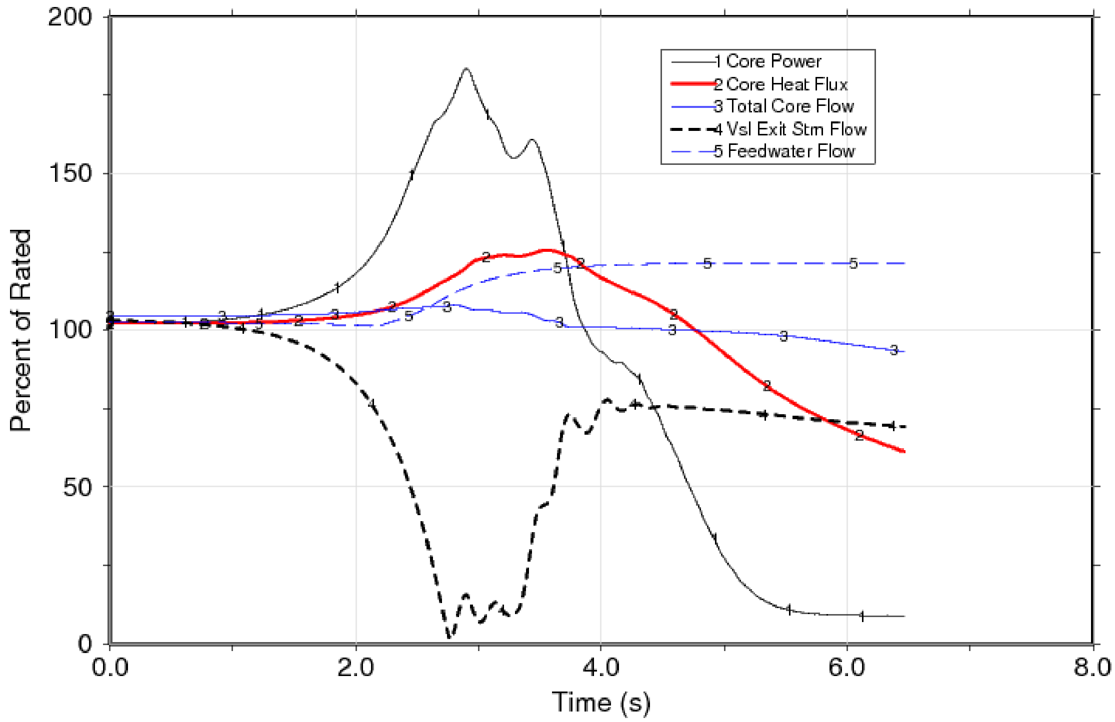

Figure 7.1 MSIV Closure Overpressurization Event at 102P/104.5F – Key Parameters

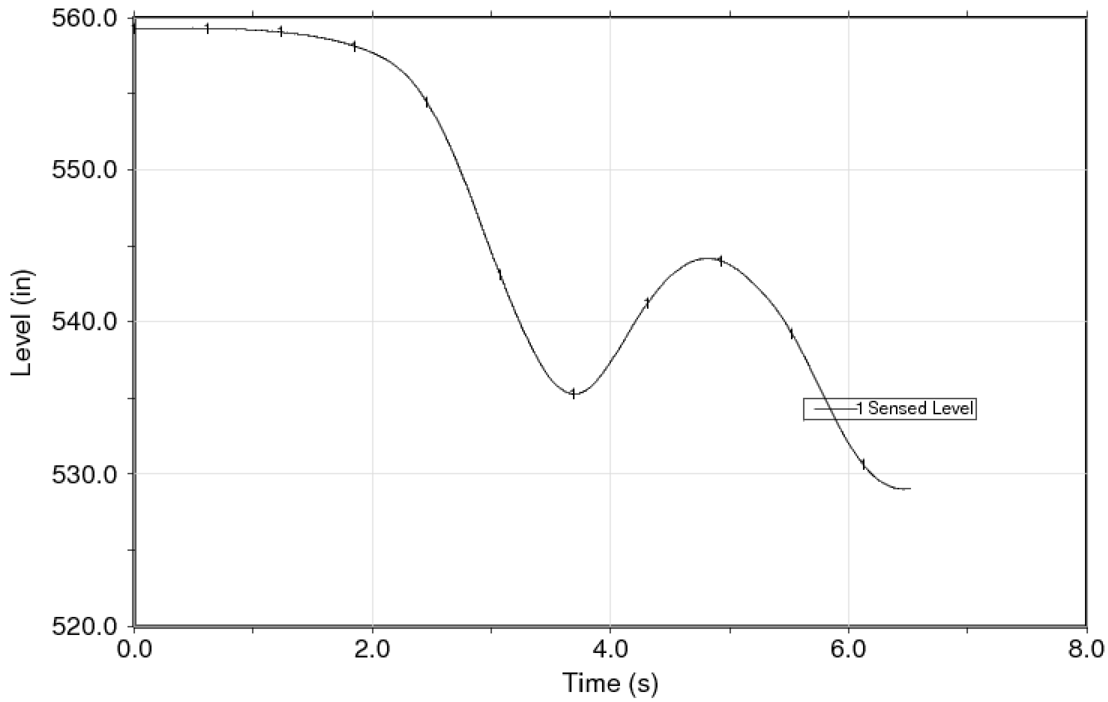

Figure 7.2 MSIV Closure Overpressurization Event at 102P/104.5F – Sensed Water Level

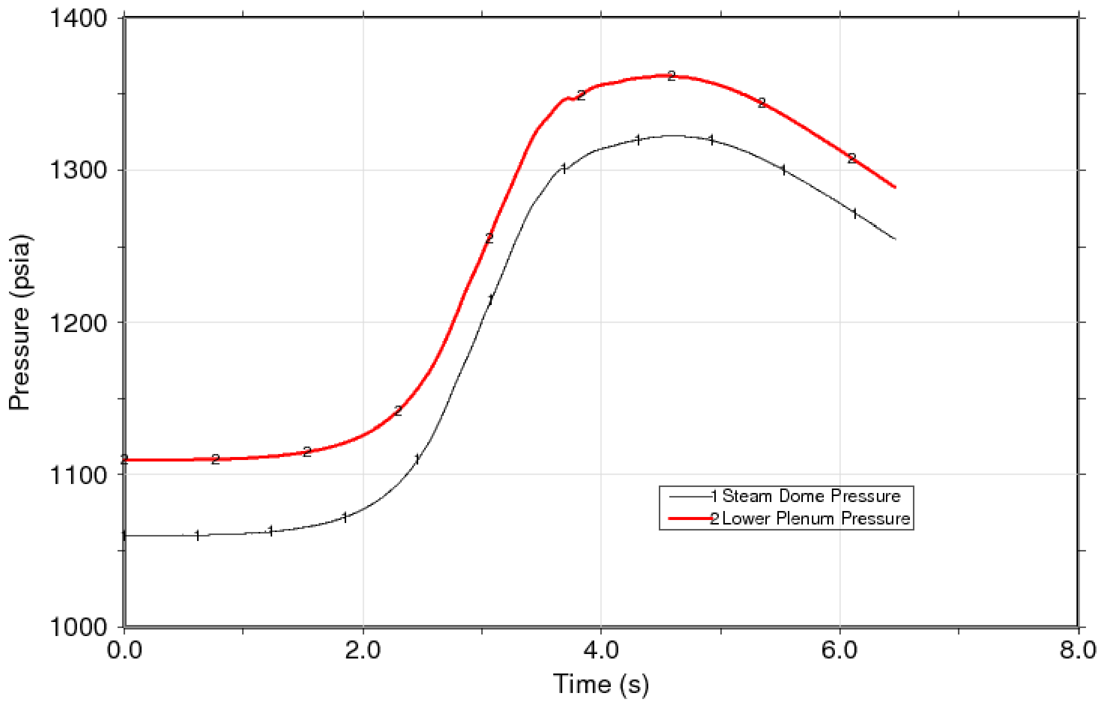

Figure 7.3 MSIV Closure Overpressurization Event at 102P/104.5F – Vessel Pressures

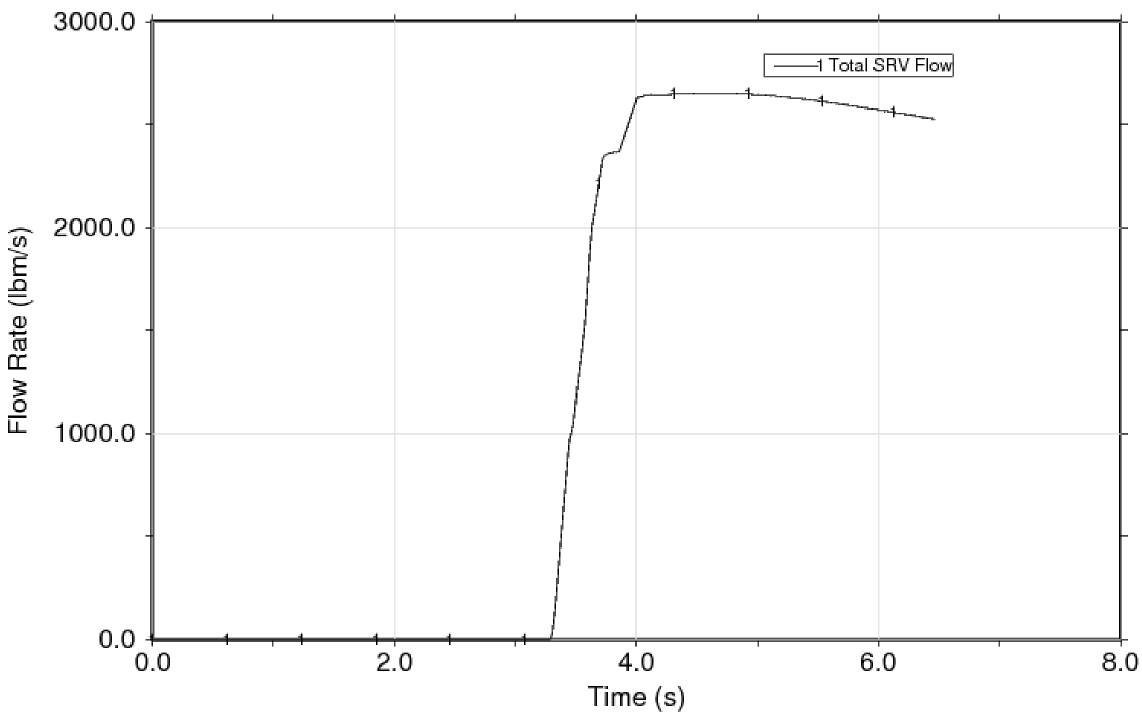

Figure 7.4 MSIV Closure Overpressurization Event at 102P/104.5F – Safety/Relief Valve Flow Rates

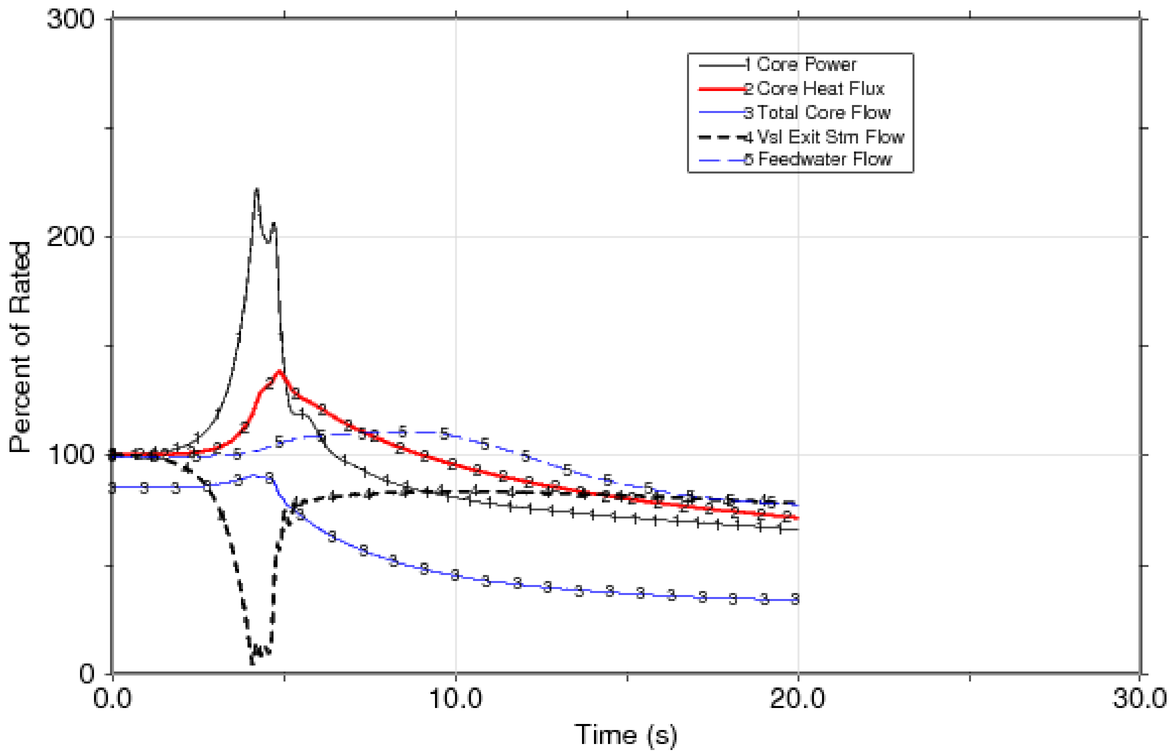

Figure 7.5 MSIV ATWS Overpressurization Event at 100P/85F – Key Parameters

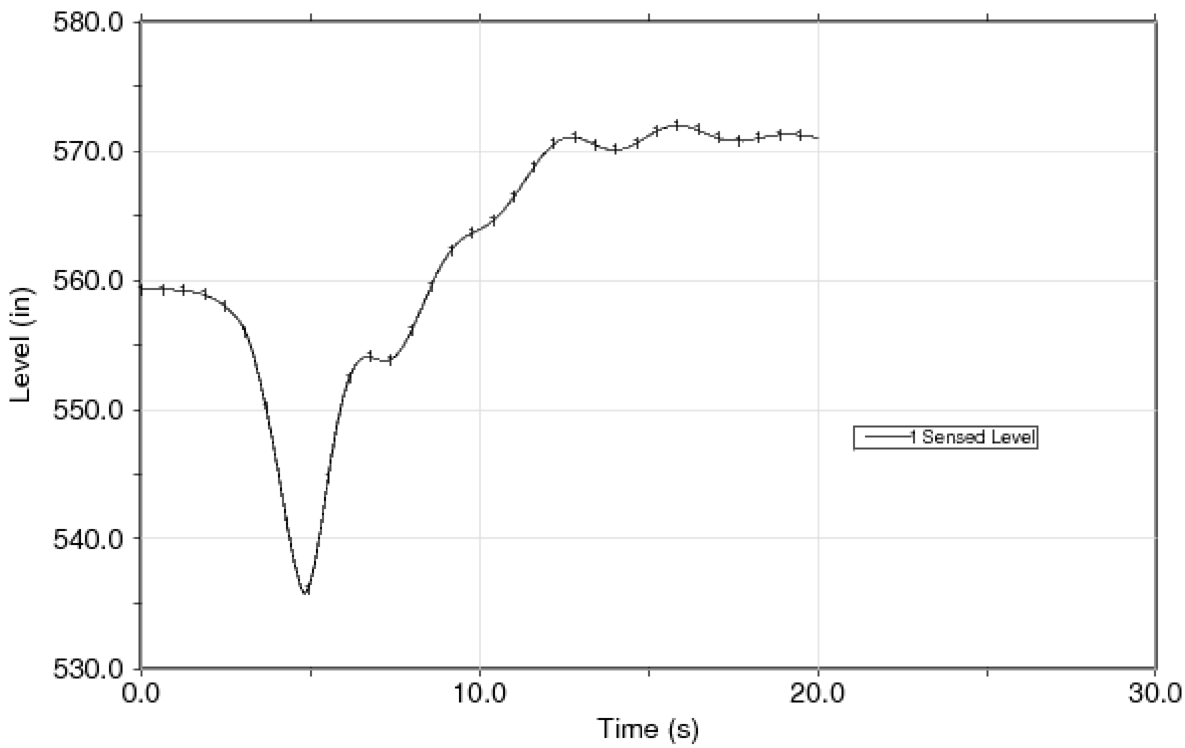

Figure 7.6 MSIV ATWS Overpressurization Event at 100P/85F – Sensed Water Level

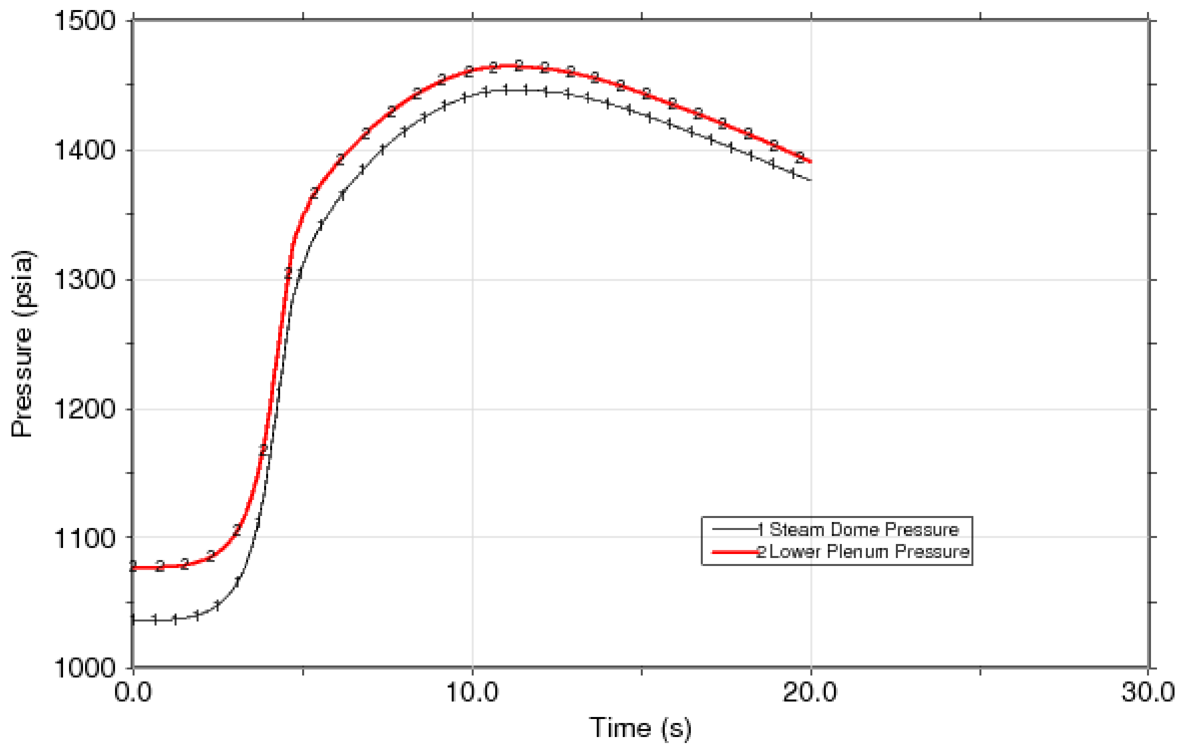

Figure 7.7 MSIV ATWS Overpressurization Event at 100P/85F – Vessel Pressures

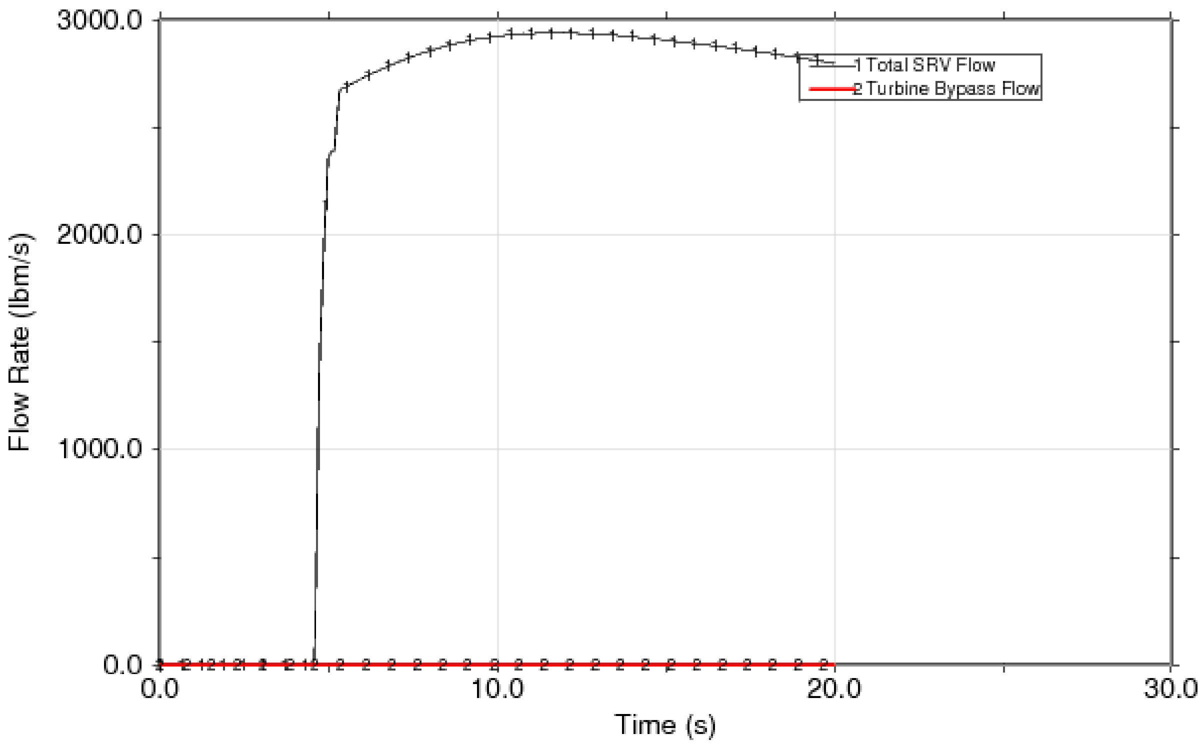

Figure 7.8 MSIV ATWS Overpressurization Event at 100P/85F – Safety/Relief Valve Flow Rates

8.0 OPERATING LIMITS AND COLR INPUT

8.1 *MCPR Limits*

The determination of the MCPR limits for Brunswick Unit 2 Cycle 25 is based on the analyses of the limiting anticipated operational occurrences (AOOs). For Brunswick Unit 2 Cycle 25, [

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The MCPR operating limits are established so that less than 0.1% of the fuel rods in the core are expected to experience boiling transition during an AOO initiated from rated or off-rated conditions and are based on a two-loop operation SLMCPR of 1.08 and a single-loop operation SLMCPR of 1.09. Exposure-dependent MCPR limits were established to support operation from BOC to near end of cycle (NEOC), BOC to end-of-cycle licensing basis (EOCLB), and combined FFTR/Coastdown as defined by the core average exposures listed in Table 5.1. MCPR limits are established to support base case operation and the EOOS scenarios presented in Table 1.1.

Cycle 25 two-loop operation $MCPR_p$ limits for ATRIUM 10XM and ATRIUM 11 fuel are presented in Tables 8.1 – 8.9 for base case operation and the EOOS conditions. Limits are presented for nominal scram speed (NSS), extended scram speed (ESS), and Technical Specification scram speed (TSSS) insertion times for the exposure ranges considered. An assumed RBM high power setpoint of 114% was used to develop the $MCPR_p$ limits. Tables 8.1 through 8.3 present the $MCPR_p$ limits for the BOC to NEOC exposure range. Tables 8.4 through 8.6 present the $MCPR_p$ limits for the BOC to EOCLB exposure range. Tables 8.7 through 8.9 present the $MCPR_p$ limits for FFTR/Coastdown operation. The FFTR/Coastdown limits (both base case and TBVOOS) support both nominal and constant rated dome pressure operation with feedwater temperatures consistent with a feedwater temperature reduction of up to 110.3°F at rated power. $MCPR_p$ limits for single-loop operation are 0.01 higher for all cases.

$MCPR_f$ limits that protect against fuel failures during a postulated slow flow excursion are presented in Tables 8.10 and 8.11. These $MCPR_f$ limits are applicable for all Cycle 25 exposures and the EOOS conditions identified in Table 1.1.

8.2 ***LHGR Limits***

The LHGR limits for ATRIUM 11 and ATRIUM 10XM are presented in Table 8.12 (References 6 and 36, respectively). 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 AOO for both UO_2 and gadolinia bearing rods.

The ATRIUM 10XM and ATRIUM 11 $LHGRFAC_p$ multipliers are determined using the RODEX4 thermal-mechanical methodology (Reference 30) using the AURORA-B transient simulations. For the LHGRFACp evaluations **[**

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Exposure-dependent ATRIUM 11 and ATRIUM 10XM $LHGRFAC_p$ multipliers were established to support operation from BOC to EOCLB (Tables 8.13 – 8.15), and combined FFTR/Coastdown (Tables 8.16 – 8.18) for NSS, ESS, and TSSS insertion times, respectively and for the EOOS conditions identified in Table 1.1. The FFTR/Coastdown limits (both base case and TBVOOS) support both nominal and constant rated dome pressure operation with feedwater temperatures consistent with a feedwater temperature reduction of up to 110.3°F at rated power.

$LHGRFAC_f$ multipliers are established to provide protection against fuel centerline melt and overstraining of the cladding during a postulated slow flow excursion. For ATRIUM 10XM and ATRIUM 11 fuel, the $LHGRFAC_f$ multipliers are presented in Table 8.19 and are applicable for all Cycle 25 exposures and the EOOS conditions identified in Table 1.1.

8.3 *MAPLHGR Limits*

The ATRIUM 10XM TLO MAPLHGR limits are presented in Table 8.20. For operation in SLO, a multiplier of 0.80 must be applied to the TLO MAPLHGR limits.

The ATRIUM 11 TLO MAPLHGR limits are presented in Table 8.20. For operation in SLO, a multiplier of 0.85 must be applied to the TLO MAPLHGR limits.

**Table 8.1 $MCPR_p$ Limits for
NSS Insertion Times
BOC to < NEOC***

EOOS Condition	Power (% rated)	ATRIUM 10XM $MCPR_p$		ATRIUM 11 $MCPR_p$	
Base case operation	100.0	1.38		1.33	
	80.0	1.48		1.38	
	50.0	1.65		1.52	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.69	1.84	1.66
	26.0	2.20	2.01	2.18	1.90
	26.0	2.21	2.06	2.20	1.99
	23.0	2.22	2.08	2.23	1.99
TBVOOS	100.0	1.38		1.36	
	80.0	1.48		1.41	
	50.0	1.65		1.61	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.69	1.84	1.66
	26.0	2.20	2.01	2.18	1.90
	26.0	2.74	2.72	2.80	2.55
	23.0	2.91	2.81	2.92	2.69
FHOOS†	100.0	1.38		1.33	
	80.0	1.48		1.38	
	50.0	1.65		1.52	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.73	1.84	1.66
	26.0	2.20	2.01	2.18	1.91
	26.0	2.21	2.08	2.20	1.99
	23.0	2.23	2.19	2.23	2.05
TBVOOS FHOOS†	100.0	1.38		1.36	
	80.0	1.48		1.44	
	50.0	1.65		1.67	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.73	1.84	1.66
	26.0	2.20	2.01	2.18	1.91
	26.0	2.89	2.77	2.97	2.55
	23.0	3.06	2.84	3.05	2.72

* Limits support operation with any combination of 1 SRVOOS, up to 40% of the TIP channels out-of-service, and up to 50% of the LPRMs out-of-service. For single-loop operation, $MCPR_p$ limits will be 0.01 higher. Note that operation in SLO is only supported up to a maximum power level of 71.1% of rated and is not allowed in MELLLA+.

† Note that FHOOS is not allowed in MELLLA+.

Table 8.2 $MCPR_p$ Limits for ESS Insertion Times BOC to < NEOC*

EOOS Condition	Power (% rated)	ATRIUM 10XM $MCPR_p$		ATRIUM 11 $MCPR_p$	
Base case operation	100.0	1.38		1.33	
	80.0	1.48		1.38	
	50.0	1.65		1.52	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.69	1.84	1.66
	26.0	2.20	2.01	2.18	1.90
	26.0	2.21	2.06	2.20	1.99
	23.0	2.22	2.08	2.23	1.99
TBVOOS	100.0	1.38		1.37	
	80.0	1.48		1.41	
	50.0	1.65		1.61	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.69	1.84	1.66
	26.0	2.20	2.01	2.18	1.90
	26.0	2.74	2.72	2.80	2.55
	23.0	2.91	2.81	2.92	2.69
FHOOS†	100.0	1.38		1.33	
	80.0	1.48		1.38	
	50.0	1.65		1.52	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.73	1.84	1.66
	26.0	2.20	2.01	2.18	1.91
	26.0	2.21	2.08	2.20	1.99
	23.0	2.23	2.19	2.23	2.05
TBVOOS FHOOS†	100.0	1.38		1.37	
	80.0	1.48		1.44	
	50.0	1.65		1.67	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.73	1.84	1.66
	26.0	2.20	2.01	2.18	1.91
	26.0	2.89	2.77	2.97	2.55
	23.0	3.06	2.84	3.05	2.72

* Limits support operation with any combination of 1 SRVOOS, up to 40% of the TIP channels out-of-service, and up to 50% of the LPRMs out-of-service. For single-loop operation, $MCPR_p$ limits will be 0.01 higher. Note that operation in SLO is only supported up to a maximum power level of 71.1% of rated and is not allowed in MELLLA+.

† Note that FHOOS is not allowed in MELLLA+.

**Table 8.3 $MCPR_p$ Limits for
TSSS Insertion Times
BOC to < NEOC***

EOOS Condition	Power (% rated)	ATRIUM 10XM $MCPR_p$		ATRIUM 11 $MCPR_p$	
Base case operation	100.0	1.38		1.36	
	80.0	1.48		1.39	
	50.0	1.65		1.60	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.69	1.84	1.66
	26.0	2.20	2.01	2.18	1.90
	26.0	2.21	2.06	2.20	1.99
	23.0	2.22	2.08	2.23	1.99
TBVOOS	100.0	1.40		1.39	
	80.0	1.48		1.45	
	50.0	1.65		1.67	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.69	1.84	1.66
	26.0	2.20	2.01	2.18	1.90
	26.0	2.74	2.72	2.80	2.55
	23.0	2.91	2.81	2.92	2.69
FHOOS†	100.0	1.38		1.36	
	80.0	1.48		1.39	
	50.0	1.65		1.60	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.73	1.84	1.66
	26.0	2.20	2.01	2.18	1.91
	26.0	2.21	2.08	2.20	1.99
	23.0	2.23	2.19	2.23	2.05
TBVOOS FHOOS†	100.0	1.40		1.39	
	80.0	1.48		1.47	
	50.0	1.65		1.70	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.73	1.84	1.66
	26.0	2.20	2.01	2.18	1.91
	26.0	2.89	2.77	2.97	2.55
	23.0	3.06	2.84	3.05	2.72

* Limits support operation with any combination of 1 SRVOOS, up to 40% of the TIP channels out-of-service, and up to 50% of the LPRMs out-of-service. For single-loop operation, $MCPR_p$ limits will be 0.01 higher. Note that operation in SLO is only supported up to a maximum power level of 71.1% of rated and is not allowed in MELLLA+.

† Note that FHOOS is not allowed in MELLLA+.

Table 8.4 $MCPR_p$ Limits for NSS Insertion Times BOC to < EOCLB*

EOOS Condition	Power (% rated)	ATRIUM 10XM $MCPR_p$		ATRIUM 11 $MCPR_p$	
Base case operation	100.0	1.38		1.36	
	80.0	1.48		1.39	
	50.0	1.65		1.52	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.69	1.84	1.66
	26.0	2.20	2.01	2.18	1.90
	26.0	2.21	2.06	2.20	1.99
	23.0	2.22	2.08	2.23	1.99
TBVOOS	100.0	1.40		1.39	
	80.0	1.48		1.45	
	50.0	1.65		1.62	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.69	1.84	1.66
	26.0	2.20	2.01	2.18	1.90
	26.0	2.74	2.72	2.80	2.55
	23.0	2.91	2.81	2.92	2.69
FHOOS†	100.0	1.38		1.36	
	80.0	1.48		1.39	
	50.0	1.65		1.52	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.73	1.84	1.66
	26.0	2.20	2.01	2.18	1.91
	26.0	2.21	2.08	2.20	1.99
	23.0	2.23	2.19	2.23	2.05
TBVOOS FHOOS†	100.0	1.41		1.41	
	80.0	1.48		1.46	
	50.0	1.65		1.67	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.73	1.84	1.66
	26.0	2.20	2.01	2.18	1.91
	26.0	2.89	2.77	2.97	2.55
	23.0	3.06	2.84	3.05	2.72

* Limits support operation with any combination of 1 SRVOOS, up to 40% of the TIP channels out-of-service, and up to 50% of the LPRMs out-of-service. For single-loop operation, $MCPR_p$ limits will be 0.01 higher. Note that operation in SLO is only supported up to a maximum power level of 71.1% of rated and is not allowed in MELLLA+.

† Note that FHOOS is not allowed in MELLLA+.

Table 8.5 $MCPR_p$ Limits for ESS Insertion Times BOC to < EOCLB*

EOOS Condition	Power (% rated)	ATRIUM 10XM $MCPR_p$		ATRIUM 11 $MCPR_p$	
Base case operation	100.0	1.38		1.36	
	80.0	1.48		1.39	
	50.0	1.65		1.52	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.69	1.84	1.66
	26.0	2.20	2.01	2.18	1.90
	26.0	2.21	2.06	2.20	1.99
	23.0	2.22	2.08	2.23	1.99
TBVOOS	100.0	1.41		1.40	
	80.0	1.48		1.45	
	50.0	1.65		1.62	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.69	1.84	1.66
	26.0	2.20	2.01	2.18	1.90
	26.0	2.74	2.72	2.80	2.55
	23.0	2.91	2.81	2.92	2.69
FHOOS[†]	100.0	1.38		1.36	
	80.0	1.48		1.39	
	50.0	1.65		1.52	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.73	1.84	1.66
	26.0	2.20	2.01	2.18	1.91
	26.0	2.21	2.08	2.20	1.99
	23.0	2.23	2.19	2.23	2.05
TBVOOS FHOOS[†]	100.0	1.41		1.41	
	80.0	1.48		1.46	
	50.0	1.65		1.67	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.73	1.84	1.66
	26.0	2.20	2.01	2.18	1.91
	26.0	2.89	2.77	2.97	2.55
	23.0	3.06	2.84	3.05	2.72

* Limits support operation with any combination of 1 SRVOOS, up to 40% of the TIP channels out-of-service, and up to 50% of the LPRMs out-of-service. For single-loop operation, $MCPR_p$ limits will be 0.01 higher. Note that operation in SLO is only supported up to a maximum power level of 71.1% of rated and is not allowed in MELLLA+.

† Note that FHOOS is not allowed in MELLLA+.

Table 8.6 MCPR$_p$ Limits for TSSS Insertion Times BOC to < EOCLB*

EOOS Condition	Power (% rated)	ATRIUM 10XM MCPR$_p$		ATRIUM 11 MCPR$_p$	
Base case operation	100.0	1.42		1.44	
	80.0	1.48		1.44	
	50.0	1.65		1.61	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.69	1.85	1.67
	26.0	2.20	2.01	2.19	1.91
	26.0	2.21	2.06	2.21	2.00
	23.0	2.22	2.08	2.24	2.00
TBVOOS	100.0	1.48		1.50	
	80.0	1.51		1.51	
	50.0	1.68		1.71	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.91	1.72	1.88	1.70
	26.0	2.23	2.04	2.22	1.94
	26.0	2.77	2.75	2.84	2.59
	23.0	2.94	2.84	2.96	2.73
FHOOS†	100.0	1.42		1.44	
	80.0	1.48		1.44	
	50.0	1.65		1.61	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.73	1.85	1.67
	26.0	2.20	2.01	2.19	1.92
	26.0	2.21	2.08	2.21	2.00
	23.0	2.23	2.19	2.24	2.06
TBVOOS FHOOS†	100.0	1.48		1.50	
	80.0	1.51		1.51	
	50.0	1.68		1.74	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.91	1.76	1.88	1.70
	26.0	2.23	2.04	2.22	1.95
	26.0	2.92	2.80	3.01	2.59
	23.0	3.09	2.87	3.09	2.76

* Limits support operation with any combination of 1 SRVOOS, up to 40% of the TIP channels out-of-service, and up to 50% of the LPRMs out-of-service. For single-loop operation, MCPR$_p$ limits will be 0.01 higher. Note that operation in SLO is only supported up to a maximum power level of 71.1% of rated and is not allowed in MELLLA+.

† Note that FHOOS is not allowed in MELLLA+.

Table 8.7 $MCPR_p$ Limits for NSS Insertion Times FFTR/Coastdown*,†

EOOS Condition	Power (% rated)	ATRIUM 10XM $MCPR_p$		ATRIUM 11 $MCPR_p$	
Base case operation	100.0	1.38		1.36	
	80.0	1.48		1.39	
	50.0	1.65		1.52	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.73	1.84	1.66
	26.0	2.20	2.01	2.18	1.91
	26.0	2.21	2.08	2.20	1.99
	23.0	2.23	2.19	2.23	2.05
TBVOOS	100.0	1.42		1.41	
	80.0	1.48		1.46	
	50.0	1.65		1.67	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.73	1.84	1.66
	26.0	2.20	2.01	2.18	1.91
	26.0	2.89	2.77	2.97	2.55
	23.0	3.06	2.84	3.05	2.72

* Limits support operation with any combination of 1 SRVOOS, up to 40% of the TIP channels out-of-service, and up to 50% of the LPRMs out-of-service. For single-loop operation, $MCPR_p$ limits will be 0.01 higher. Note that operation in SLO is only supported up to a maximum power level of 71.1% of rated and is not allowed in MELLLA+.

† Note that reduced feedwater temperatures such as FFTR are not allowed in MELLLA+; however, the FFTR/Coastdown limits may be conservatively applied to operation in the MELLLA+ domain at these exposures.

Table 8.8 $MCPR_p$ Limits for ESS Insertion Times FFTR/Coastdown*,†

EOOS Condition	Power (% rated)	ATRIUM 10XM $MCPR_p$		ATRIUM 11 $MCPR_p$	
Base case operation	100.0	1.38		1.36	
	80.0	1.48		1.39	
	50.0	1.65		1.52	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.73	1.84	1.66
	26.0	2.20	2.01	2.18	1.91
	26.0	2.21	2.08	2.20	1.99
	23.0	2.23	2.19	2.23	2.05
TBVOOS	100.0	1.42		1.41	
	80.0	1.48		1.46	
	50.0	1.65		1.67	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.88	1.73	1.84	1.66
	26.0	2.20	2.01	2.18	1.91
	26.0	2.89	2.77	2.97	2.55
	23.0	3.06	2.84	3.05	2.72

* Limits support operation with any combination of 1 SRVOOS, up to 40% of the TIP channels out-of-service, and up to 50% of the LPRMs out-of-service. For single-loop operation, $MCPR_p$ limits will be 0.01 higher. Note that operation in SLO is only supported up to a maximum power level of 71.1% of rated and is not allowed in MELLLA+.

† Note that reduced feedwater temperatures such as FFTR are not allowed in MELLLA+; however, the FFTR/Coastdown limits may be conservatively applied to operation in the MELLLA+ domain at these exposures.

Table 8.9 $MCPR_p$ Limits for TSSS Insertion Times FFTR/Coastdown*,†

EOOS Condition	Power (% rated)	ATRIUM 10XM $MCPR_p$		ATRIUM 11 $MCPR_p$	
Base case operation	100.0	1.46		1.46	
	80.0	1.50		1.46	
	50.0	1.67		1.62	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.90	1.75	1.86	1.68
	26.0	2.22	2.03	2.20	1.93
	26.0	2.23	2.10	2.22	2.01
	23.0	2.25	2.21	2.25	2.07
TBVOOS	100.0	1.52		1.52	
	80.0	1.53		1.53	
	50.0	1.70		1.75	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	1.93	1.78	1.89	1.71
	26.0	2.25	2.06	2.23	1.96
	26.0	2.94	2.82	3.02	2.60
	23.0	3.11	2.89	3.10	2.77

* Limits support operation with any combination of 1 SRVOOS, up to 40% of the TIP channels out-of-service, and up to 50% of the LPRMs out-of-service. For single-loop operation, $MCPR_p$ limits will be 0.01 higher. Note that operation in SLO is only supported up to a maximum power level of 71.1% of rated and is not allowed in MELLLA+.

† Note that reduced feedwater temperatures such as FFTR are not allowed in MELLLA+; however, the FFTR/Coastdown limits may be conservatively applied to operation in the MELLLA+ domain at these exposures.

Table 8.10 Flow-Dependent MCPR Limits
ATRIUM 10XM Fuel

Core Flow (% of rated)	$MCPR_f$ MSIVIS	$MCPR_f$ MSIVOOS
0.0	1.48	1.65
31.0	1.48	1.65
60.0	1.42	1.50
75.0	1.30	---
81.0	---	1.31
107.0	1.30	1.31

Table 8.11 Flow-Dependent MCPR Limits
ATRIUM 11 Fuel

Core Flow (% of rated)	$MCPR_f$ MSIVIS	$MCPR_f$ MSIVOOS
0.0	1.42	1.52
31.0	1.42	1.52
60.0	1.31	---
77.0	---	1.31
107.0	1.31	1.31

Table 8.12 Steady-State LHGR Limits

Peak Pellet Exposure (GWd/MTU)	ATRIUM 10XM LHGR (kW/ft)	Peak Pellet Exposure (GWd/MTU)	ATRIUM 11 LHGR (kW/ft)
0.0	15.1	0.0	13.6
6.0	14.1	--*	--
18.9	14.1	21.0	13.6
54.0	10.6	53.0	10.2
74.4	5.4	80.0	3.5

* “--“ indicates that the ATRIUM 11 limit does not include any breakpoint at this exposure.

Table 8.13 LHGRFAC$_p$ Multipliers for NSS Insertion Times BOC to < EOCLB

EOOS Condition	Power (% rated)	ATRIUM 10XM LHGRFAC$_p$		ATRIUM 11 LHGRFAC$_p$	
Base case operation	100.0	1.00		1.00	
	90.0	1.00		1.00	
	50.0	1.00		1.00	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	0.93	1.00	0.86	0.95
	26.0	0.75	0.86	0.68	0.80
	26.0	0.75	0.84	0.68	0.80
	23.0	0.71	0.83	0.64	0.78
TBVOOS	100.0	1.00		1.00	
	90.0	1.00		1.00	
	50.0	0.98		0.97	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	0.93	1.00	0.86	0.95
	26.0	0.75	0.86	0.68	0.80
	26.0	0.45	0.56	0.41	0.51
	23.0	0.41	0.50	0.38	0.46
FHOOS*	100.0	1.00		1.00	
	90.0	1.00		1.00	
	50.0	1.00		0.96	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	0.93	1.00	0.86	0.95
	26.0	0.75	0.86	0.68	0.80
	26.0	0.65	0.78	0.61	0.75
	23.0	0.63	0.77	0.59	0.71
TBVOOS FHOOS*	100.0	1.00		1.00	
	90.0	1.00		1.00	
	50.0	0.97		0.90	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	0.92	1.00	0.86	0.95
	26.0	0.75	0.86	0.68	0.80
	26.0	0.42	0.52	0.38	0.48
	23.0	0.38	0.47	0.35	0.43

* Note that FHOOS is not allowed in MELLLA+.

Table 8.14 $LHGRFAC_p$ Multipliers for ESS Insertion Times BOC to < EOCLB

EOOS Condition	Power (% rated)	ATRIUM 10XM $LHGRFAC_p$		ATRIUM 11 $LHGRFAC_p$	
Base case operation	100.0	1.00		1.00	
	90.0	1.00		1.00	
	50.0	1.00		1.00	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	0.93	1.00	0.86	0.95
	26.0	0.75	0.86	0.68	0.80
	26.0	0.75	0.84	0.68	0.80
	23.0	0.71	0.83	0.64	0.78
TBVOOS	100.0	1.00		1.00	
	90.0	1.00		1.00	
	50.0	0.98		0.97	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	0.93	1.00	0.86	0.95
	26.0	0.75	0.86	0.68	0.80
	26.0	0.45	0.56	0.41	0.51
	23.0	0.41	0.50	0.38	0.46
FHOOS*	100.0	1.00		1.00	
	90.0	1.00		1.00	
	50.0	1.00		0.96	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	0.93	1.00	0.86	0.95
	26.0	0.75	0.86	0.68	0.80
	26.0	0.65	0.78	0.61	0.75
	23.0	0.63	0.77	0.59	0.71
TBVOOS FHOOS*	100.0	1.00		1.00	
	90.0	1.00		1.00	
	50.0	0.97		0.90	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	0.92	1.00	0.86	0.95
	26.0	0.75	0.86	0.68	0.80
	26.0	0.42	0.52	0.38	0.48
	23.0	0.38	0.47	0.35	0.43

* Note that FHOOS is not allowed in MELLLA+.

Table 8.15 LHGRFAC$_p$ Multipliers for TSSS Insertion Times BOC to < EOCLB

EOOS Condition	Power (% rated)	ATRIUM 10XM LHGRFAC$_p$		ATRIUM 11 LHGRFAC$_p$	
Base case operation	100.0	1.00		1.00	
	90.0	1.00		-	
	50.0	1.00		1.00	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	0.93	1.00	0.86	0.95
	26.0	0.75	0.86	0.68	0.80
	26.0	0.75	0.84	0.68	0.80
	23.0	0.71	0.83	0.64	0.78
TBVOOS	100.0	1.00		1.00	
	90.0	1.00		-	
	50.0	0.98		0.92	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	0.93	1.00	0.86	0.95
	26.0	0.75	0.86	0.68	0.80
	26.0	0.45	0.56	0.41	0.51
	23.0	0.41	0.50	0.38	0.46
FHOOS*	100.0	1.00		1.00	
	90.0	1.00		-	
	50.0	1.00		0.95	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	0.93	1.00	0.86	0.95
	26.0	0.75	0.86	0.68	0.80
	26.0	0.65	0.78	0.61	0.75
	23.0	0.63	0.77	0.59	0.71
TBVOOS FHOOS*	100.0	1.00		0.97	
	90.0	1.00		-	
	50.0	0.92		0.87	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	0.92	1.00	0.86	0.95
	26.0	0.75	0.86	0.68	0.80
	26.0	0.42	0.52	0.38	0.48
	23.0	0.38	0.47	0.35	0.43

* Note that FHOOS is not allowed in MELLLA+.

Table 8.16 LHGRFAC$_p$ Multipliers for NSS Insertion Times FFTR/Coastdown*

EOOS Condition	Power (% rated)	ATRIUM 10XM LHGRFAC$_p$		ATRIUM 11 LHGRFAC$_p$	
Base case operation	100.0	1.00		1.00	
	90.0	1.00		1.00	
	50.0	1.00		0.96	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	0.93	1.00	0.86	0.95
	26.0	0.75	0.86	0.68	0.80
	26.0	0.65	0.78	0.61	0.75
	23.0	0.63	0.77	0.59	0.71
TBVOOS	100.0	1.00		1.00	
	90.0	1.00		1.00	
	50.0	0.97		0.90	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	0.92	1.00	0.86	0.95
	26.0	0.75	0.86	0.68	0.80
	26.0	0.42	0.52	0.38	0.48
	23.0	0.38	0.47	0.35	0.43

* Note that reduced feedwater temperatures such as FFTR are not allowed in MELLLA+; however, the FFTR/Coastdown limits may be conservatively applied to operation in the MELLLA+ domain at these exposures.

Table 8.17 $LHGRFAC_p$ Multipliers for ESS Insertion Times FFTR/Coastdown*

<table>
<tr><th>EOOS Condition</th><th>Power (% rated)</th><th colspan="2">ATRIUM 10XM LHGRFAC_p</th><th colspan="2">ATRIUM 11 LHGRFAC_p</th></tr>
<tr><td rowspan="9">Base case operation</td><td>100.0</td><td colspan="2">1.00</td><td colspan="2">1.00</td></tr>
<tr><td>90.0</td><td colspan="2">1.00</td><td colspan="2">1.00</td></tr>
<tr><td>50.0</td><td colspan="2">1.00</td><td colspan="2">0.96</td></tr>
<tr><td></td><td>> 65%F</td><td>≤ 65%F</td><td>> 65%F</td><td>≤ 65%F</td></tr>
<tr><td>50.0</td><td>0.93</td><td>1.00</td><td>0.86</td><td>0.95</td></tr>
<tr><td>26.0</td><td>0.75</td><td>0.86</td><td>0.68</td><td>0.80</td></tr>
<tr><td>26.0</td><td>0.65</td><td>0.78</td><td>0.61</td><td>0.75</td></tr>
<tr><td>23.0</td><td>0.63</td><td>0.77</td><td>0.59</td><td>0.71</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td rowspan="8">TBVOOS</td><td>100.0</td><td colspan="2">1.00</td><td colspan="2">1.00</td></tr>
<tr><td>90.0</td><td colspan="2">1.00</td><td colspan="2">1.00</td></tr>
<tr><td>50.0</td><td colspan="2">0.97</td><td colspan="2">0.90</td></tr>
<tr><td></td><td>> 65%F</td><td>≤ 65%F</td><td>> 65%F</td><td>≤ 65%F</td></tr>
<tr><td>50.0</td><td>0.92</td><td>1.00</td><td>0.86</td><td>0.95</td></tr>
<tr><td>26.0</td><td>0.75</td><td>0.86</td><td>0.68</td><td>0.80</td></tr>
<tr><td>26.0</td><td>0.42</td><td>0.52</td><td>0.38</td><td>0.48</td></tr>
<tr><td>23.0</td><td>0.38</td><td>0.47</td><td>0.35</td><td>0.43</td></tr>
</table>

* Note that reduced feedwater temperatures such as FFTR are not allowed in MELLLA+; however, the FFTR/Coastdown limits may be conservatively applied to operation in the MELLLA+ domain at these exposures.

Table 8.18 LHGRFAC$_p$ Multipliers for TSSS Insertion Times FFTR/Coastdown*

EOOS Condition	Power (% rated)	ATRIUM 10XM LHGRFAC$_p$		ATRIUM 11 LHGRFAC$_p$	
Base case operation	100.0	1.00		1.00	
	90.0	1.00		-	
	50.0	1.00		0.95	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	0.93	1.00	0.86	0.95
	26.0	0.75	0.86	0.68	0.80
	26.0	0.65	0.78	0.61	0.75
	23.0	0.63	0.77	0.59	0.71
TBVOOS	100.0	1.00		0.97	
	90.0	1.00		-	
	50.0	0.92		0.87	
		> 65%F	≤ 65%F	> 65%F	≤ 65%F
	50.0	0.92	1.00	0.86	0.95
	26.0	0.75	0.86	0.68	0.80
	26.0	0.42	0.52	0.38	0.48
	23.0	0.38	0.47	0.35	0.43

* Note that reduced feedwater temperatures such as FFTR are not allowed in MELLLA+; however, the FFTR/Coastdown limits may be conservatively applied to operation in the MELLLA+ domain at these exposures.

Table 8.19 ATRIUM 10XM and ATRIUM 11 $LHGRFAC_f$ Multipliers
All Cycle 25 Exposures

Core Flow (% of rated)	$LHGRFAC_f$
0.0	0.52
31.0	0.52
75.0	1.00
107.0	1.00

Table 8.20 Framatome Fuel
MAPLHGR Limits

Average Planar Exposure (GWd/MTU)	ATRIUM 10XM MAPLHGR (kW/ft)	Average Planar Exposure (GWd/MTU)	ATRIUM 11 MAPLHGR (kW/ft)
0.0	13.1	0.0	12.0
15.0	13.1	20.0	12.0
67.0	7.7	60.0	9.0
--	--	69.0	7.2

Figure 8.1 [

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Figure 8.2 [

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Affidavit for ANP-3897P

AFFIDAVIT

1. My name is Alan B. Meginnis. I am Manager, Product Licensing, for Framatome Inc. and as such I am authorized to execute this Affidavit.

2. I am familiar with the criteria applied by Framatome to determine whether certain Framatome information is proprietary. I am familiar with the policies established by Framatome to ensure the proper application of these criteria.

3. I am familiar with the Framatome information contained in the report ANP-3897P Revision 0, "Brunswick Unit 2 Cycle 25 Reload Safety Analysis," dated January 2021 and referred to herein as "Document." Information contained in this Document has been classified by Framatome as proprietary in accordance with the policies established by Framatome for the control and protection of proprietary and confidential information.

4. This Document contains information of a proprietary and confidential nature and is of the type customarily held in confidence by Framatome and not made available to the public. Based on my experience, I am aware that other companies regard information of the kind contained in this Document as proprietary and confidential.

5. This Document has been made available to the U.S. Nuclear Regulatory Commission in confidence with the request that the information contained in this Document be withheld from public disclosure. The request for withholding of proprietary information is made in accordance with 10 CFR 2.390. The information for which withholding from disclosure is requested qualifies under 10 CFR 2.390(a)(4) "Trade secrets and commercial or financial information."

6. The following criteria are customarily applied by Framatome to determine whether information should be classified as proprietary:

(a) The information reveals details of Framatome's research and development plans and programs or their results.

(b) Use of the information by a competitor would permit the competitor to significantly reduce its expenditures, in time or resources, to design, produce, or market a similar product or service.

(c) The information includes test data or analytical techniques concerning a process, methodology, or component, the application of which results in a competitive advantage for Framatome.

(d) The information reveals certain distinguishing aspects of a process, methodology, or component, the exclusive use of which provides a competitive advantage for Framatome in product optimization or marketability.

(e) The information is vital to a competitive advantage held by Framatome, would be helpful to competitors to Framatome, and would likely cause substantial harm to the competitive position of Framatome.

The information in the Document is considered proprietary for the reasons set forth in paragraphs 6(b), 6(d) and 6(e) above.

7. In accordance with Framatome's policies governing the protection and control of information, proprietary information contained in this Document have been made available, on a limited basis, to others outside Framatome only as required and under suitable agreement providing for nondisclosure and limited use of the information.

8. Framatome policy requires that proprietary information be kept in a secured file or area and distributed on a need-to-know basis.

9. The foregoing statements are true and correct to the best of my knowledge, information, and belief.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on: January 29, 2021

Alan B. Meginnis