Enclosure

Browns Ferry Nuclear Plant (BFN)

ANP-2631 Revision 0
Browns Ferry Unit 3 Cycle 14
Reload Analysis Report

ANP-2631
Revision 0

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May 2007

AREVA NP Inc.

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Reload Analysis

sjp/paj

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Nature of Changes

Item	Page	Description and Justification
1.	All	This is a new document.

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Nomenclature

AOT	abnormal operational transient
ARO	all rods out
ASME	American Society of Mechanical Engineers
AST	alternative source term
BOC	beginning of cycle
BPWS	banked position withdrawal sequence
CGU	commercial grade uranium
CPR	critical power ratio
CRDA	control rod drop accident
CRWE	control rod withdrawal error
EFPD	effective full-power days
EOC	end of cycle
EOC-RPT-OOS	end of cycle recirculation pump trip out-of-service
EOD	extended operating domain
EOFPL	end of full power life (100%P/100%F normal FW temperature)
EOOS	equipment out-of-service
FFTR	final feedwater temperature reduction
FHOOS	feedwater heaters out-of-service
FWCF	feedwater controller failure
ICF	increased core flow
LFWH	loss of feedwater heating
LHGR	linear heat generation rate
$LHGRFAC_f$	flow-dependent linear heat generation rate factors
$LHGRFAC_p$	power-dependent linear heat generation rate factors
LOCA	loss-of-coolant accident
LPRM	local power range monitor
LRNB	load rejection no bypass
$MAPFAC_f$	flow-dependent maximum average planar heat generation rate factors
$MAPFAC_p$	power-dependent maximum average planar heat generation rate factors
MAPLHGR	maximum average planar linear heat generation rate
MCPR	minimum critical power ratio
$MCPR_f$	flow-dependent minimum critical power ratio
$MCPR_p$	power-dependent minimum critical power ratio
MELLLA	maximum extended load line limit analysis
MSIV	main steam isolation valve
MSRVOOS	main steam relief valves out-of-service

Nomenclature *(Continued)*

NEOC	near end of cycle
NRC	Nuclear Regulatory Commission, U.S.
NSS	nominal scram speed
OLMCPR	operating limit minimum critical power ratio
OOS	out of service
OPRM	oscillation power range monitor
PAPT	protection against power transient
PCT	peak clad temperature
PLUOOS	power load unbalance out-of-service
RBM	rod block monitor
RNW	reduced notch worth
RPT	recirculation pump trip
SER	safety evaluation report
SLC	standby liquid control (boron)
SLCSDM	standby liquid control shutdown margin (boron)
SLMCPR	safety limit minimum critical power ratio
SLO	single-loop operation
TBVOOS	turbine bypass valves out-of-service
TIP	traversing in-core probe
TIPOOS	traversing in-core probe out-of-service
TLO	two-loop operation
TSSS	technical specification scram speed
UFSAR	updated final safety analysis report
ΔCPR	change in critical power ratio

1.0 Introduction

This report provides results of analyses performed by AREVA NP* as part of the reload analysis. This report is intended to be used in conjunction with the AREVA topical Report XN-NF-80-19(P)(A) Volume 4 Revision 1, *Exxon Nuclear Methodology for Boiling Water Reactors: Application of the ENC Methodology to BWR Reloads*, which describes the analyses performed in support of this reload, identifies the methodology used for those analyses, and provides a generic reference list. Section numbers in this report are the same as corresponding section numbers in XN-NF-80-19(P)(A) Volume 4 Revision 1. Methodology used in this report which supersedes XN-NF-80-19(P)(A) Volume 4 Revision 1 is referenced in Section 8.0. The application of the methodology used in the computer codes that were utilized in performing the analyses presented in this report were applied in accordance with the NRC technical limitations (safety evaluation report (SER) restrictions) as stated in the methodology.

The core consists of a total of 764 fuel assemblies, including 374 unirradiated ATRIUM™-10† assemblies and 390 irradiated ATRIUM-10 assemblies. The reference core configuration is described in Section 4.2.

The effects of channel bow are explicitly accounted for in the safety limit analysis. The Extended Operating Domain (EOD) and Equipment Out-Of-Service (EOOS) conditions presented in Table 1.1 are supported.

* AREVA NP Inc. is an AREVA and Siemens company.

† ATRIUM is a trademark of AREVA NP.

Table 1.1 EOD and EOOS Operating Conditions

Extended Operating Domain (EOD) Conditions
Increased core flow (ICF)
Maximum extended load line limit analysis (MELLLA)
Combined FFTR/coastdown

Equipment Out-of-Service (EOOS) Conditions*
Turbine bypass valves out-of-service (TBVOOS)
EOC recirculation pump trip out-of-service (EOC-RPT-OOS)
Feedwater heaters out-of-service (FHOOS)
Power load unbalance out-of-service (PLUOOS)
Combined EOC-RPT-OOS and TBVOOS
Combined EOC-RPT-OOS and FHOOS
Combined EOC-RPT-OOS and PLUOOS
Combined TBVOOS and FHOOS
Combined TBVOOS and PLUOOS
Combined FHOOS and PLUOOS
Combined EOC-RPT-OOS, TBVOOS, and FHOOS
Combined EOC-RPT-OOS, TBVOOS, and PLUOOS
Combined EOC-RPT-OOS, FHOOS, and PLUOOS
Combined TBVOOS, FHOOS, and PLUOOS
Combined EOC-RPT-OOS, TBVOOS, FHOOS, and PLUOOS
Single-loop operation (SLO)

* SLO may be combined with all of the other EOOS conditions. Base case and each EOOS condition is supported in combination with 1 MSRVOOS, up to 2 TIPOOS or the equivalent number of channels (per operating requirements defined in Reference 9.6 Section 3.2), and/or up to 50% of the LPRMs out-of-service.

2.0 Fuel Mechanical Design Analysis

Applicable AREVA Fuel Design Reports — References 9.11, 9.12, and 9.16

To assure the power history for the ATRIUM-10 fuel is bounded by the assumed power history in the fuel mechanical design analyses, LHGR operating limits have been specified in Section 7.2.3. In addition, ATRIUM-10 LHGR limits for Abnormal Operational Transients (AOTs) have been specified in References 9.11, 9.12, and 9.16 (AOT is equivalent to anticipated operational occurrences used in References 9.11, 9.12, and 9.16). The exposure limits for the ATRIUM-10 bundles are specified in References 9.11, 9.12, and 9.16.

3.0 Thermal-Hydraulic Design Analysis

3.2 *Hydraulic Characterization*

3.2.1 Hydraulic Compatibility

Hydraulic demand curves for the ATRIUM-10 fuel are provided in Reference 9.1, Figures 3.2, 3.3, and 3.4. All thermal-hydraulic compatibility criteria have been met.

3.2.3 Fuel Centerline Temperature

Applicable Reports	
ATRIUM-10	References 9.11, 9.12, and 9.16, Figure 3.2

3.2.5 Bypass Flow

Calculated Bypass Flow Fraction at 100%P/100%F (includes water channel flow)	14.4%

3.3 *MCPR Fuel Cladding Integrity Safety Limit (SLMCPR)*

Two-Loop Operation*	1.09	Reference 9.6
Single-Loop Operation*	1.11	

3.3.1 Coolant Thermodynamic Condition

Thermal Power (at SLMCPR)†	5655.11 MWt
Feedwater Flow Rate (at SLMCPR)	23.49 Mlbm/hr
Steam Dome Pressure (at rated conditions)	1050 psia
Feedwater Temperature	394.8°F

* Includes the effects of channel bow, 2 TIPOOS or the equivalent number of TIP channels (per operating requirements defined in Reference 9.6 Section 3.2), a 2500 EFPH LPRM calibration interval, and up to 50% of the LPRMs out of service

† Thermal power at SLMCPR is specific to SLMCPR methodology (Reference 8.2). The methodology increases ("pushes") the core power to reach the SLMCPR.

3.4 *Licensing Power and Exposure Shape*

The licensing axial power profile used by AREVA for the plant transient analyses bounds the projected end of full power (EOFP) axial power profile. The conservative licensing axial power profile as well as the corresponding axial exposure ratio are given in Table 3.1. Future projected cycle power profiles are considered to be in compliance when the EOFP normalized power generated in the core is greater than the licensing axial power profile at the given state conditions when the comparison is made over the bottom third of the core height.

Table 3.1 Licensing Basis Core Average Axial Power Profile and Licensing Axial Exposure Ratio

State Conditions for Power Shape Evaluation	
Power, MWt	3952.0
Core pressure, psia	1064.7
Inlet subcooling, Btu/lbm	-27.75
Flow, Mlb/hr	107.62
Control state	ARO
Core average exposure (EOFPL + 15 EFPD), MWd/MTU	31,606

Licensing Axial Power Profile *(Normalized)*

Node	Power
Top 25	0.222
24	0.684
23	0.893
22	1.021
21	1.116
20	1.183
19	1.232
18	1.270
17	1.297
16	1.373
15	1.386
14	1.393
13	1.387
12	1.370
11	1.340
10	1.293
9	1.218
8	1.109
7	0.973
6	0.830
5	0.705
4	0.614
3	0.543
2	0.432
Bottom 1	0.116

Licensing Axial Exposure Ratio (EOFP + 15 EFPD, ARO)

Average Bottom 8 ft / 12 ft = 1.0573

4.0 Nuclear Design Analysis

4.1 *Fuel Bundle Nuclear Design Analysis*

The fuel cycle design used as the basis for the reload analysis is described in Reference 9.3. The core composition is presented in Table 4.1 and Figure 4.1. The detailed fuel bundle design information for the fresh ATRIUM-10 fuel is provided in Reference 9.2. The following summary provides the appropriate cross-reference.

Assembly Average Enrichment (ATRIUM-10 fuel)

A10-4218B-15GV80-FCC	(FT4)*	4.22 wt%
A10-4218B-13GV80-FCC	(FT5)	4.22 wt%
A10-3757B-10GV80-FCC	(FT6)	3.76 wt%

Radial Enrichment Distribution (enriched lattices only)

A10B-4545L-15G80-FCC	Reference 9.2, Figure D.2
A10B-4557L-13G80-FCC	Reference 9.2, Figure D.3
A10T-4386L-13G80-FCC	Reference 9.2, Figure D.4
A10T-4386L-12G50-FCC	Reference 9.2, Figure D.5
A10B-4543L-13G80-FCC	Reference 9.2, Figure D.8
A10T-4399L-11G80-FCC	Reference 9.2, Figure D.9
A10T-4399L-11G50-FCC	Reference 9.2, Figure D.10
A10B-3997L-10G80-FCC	Reference 9.2, Figure D.13
A10T-3997L-8G80-FCC	Reference 9.2, Figure D.14
A10T-3997L-8G50-FCC	Reference 9.2, Figure D.15

Axial Enrichment Distribution	Reference 9.2, Figures 2.1-2.3
Burnable Absorber Distribution	Reference 9.2, Figures 2.4-2.6
Non-Fueled Rods	Reference 9.2, Figures 2.4-2.6
Neutronic Design Parameters	Table 4.3

* See Figure 4.1 for fuel type definitions.

Fuel Storage

Spent Fuel Storage Pool — Reference 9.4

The BFE3-14 reload batch fuel design meets the criticality safety limitations defined in Table 2.1 of Reference 9.4 and therefore can be safely stored in the pool.

New Fuel Storage Vault — Reference 9.14

The BFE3-14 reload batch can be safely stored in the new fuel storage vault per the criticality safety limits defined in Table 2.1 of Reference 9.14.

Shipping Container — References 9.19 and 9.20

The BFE3-14 reload assemblies conform to the nuclear criticality requirements established for the RAJ-II shipping container in Reference 9.19. Satisfying the Reference 9.19 requirements ensures that the BFE3-14 fuel design may be stacked according to the constraints of the RAJ-II shipping container stacking analysis provided in Reference 9.20.

4.2 *Core Nuclear Design Analysis*

4.2.1 Core Configuration

Core Configuration	Figure 4.1
Core Exposure at EOC 13, MWd/MTU* (nominal value)	34,100
Core Exposure at EOC 13, MWd/MTU (short window)	33,565
Core Exposure at EOC 13, MWd/MTU (long window)	34,634
Core Exposure at BOC 14, MWd/MTU (from nominal EOC 13)	13,034
Core Exposure at NEOC,† MWd/MTU (from nominal EOC 13)	27,834
Core Exposure at EOC (EOFPL + 15 EFPD),‡ MWd/MTU (from nominal EOC 13)	31,606
Maximum Core Exposure,§ MWd/MTU	32,637

4.2.2 Core Reactivity Characteristics**, ††

BOC 14 cold k-eff, all rods out	1.1279
BOC 14 cold k-eff, all rods in	0.9654
BOC 14 cold k-eff, strongest rod out	0.9896
BOC 14 cold shutdown margin	1.04% $\Delta k/k$
Reactivity defect/R-value (minimum CSDM at 18,833 MWd/MTU cycle exposure)	0.01% $\Delta k/k$

* The thermal limits provided in this report are applicable for an EOC 13 exposure between the long and short windows.

† NEOC analyses and limits are applicable up to this core exposure.

‡ EOC analyses and limits are applicable up to this core exposure.

§ FFTR/coastdown analyses and limits are applicable up to this core exposure.

** k-eff data are bias corrected. Bias corrected k=1+[k(MCB2)-k(target)].

†† Evaluated based on short window.

Standby liquid control (SLC)* system reactivity, 816 ppm at 366°F (equivalent to 720 ppm at 68°F)†

- Maximum k-eff 0.9798
- Minimum SLCSDM 2.02% Δk/k

* A minimum SLCSDM of 0.88% Δk/k is required to protect manufacturing and calculational uncertainties when analyzed at temperature of RHR initialization.

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

4.2.4 Core Hydrodynamic Stability

Browns Ferry has implemented BWROG Long Term Stability Solution Option III (Oscillation Power Range Monitor-OPRM). Reload validation has been performed in accordance with Reference 9.9. The stability based Operating Limit MCPR (OLMCPR) is provided for two conditions as a function of OPRM amplitude setpoint in Table 4.2. The two conditions evaluated are for a postulated oscillation at 45% core flow steady state operation (SS) and following a two recirculation pump trip (2PT) from the limiting full power operation state point. Current power and flow dependent limits provide adequate protection against violation of the Safety Limit MCPR for postulated reactor instability as long as the operating limit is greater than or equal to the specified value for the selected OPRM setpoint.

Evaluations by General Electric have shown that the generic DIVOM curves specified in NEDO-32465-A, may not be conservative for current plant operating conditions for plants which have implemented Stability Option III. Specifically, a non-conservative deficiency has been identified for high peak bundle power-to-flow ratios in the generic regional mode DIVOM curve. The deficiency results in a non-conservative slope of the associated DIVOM curve so that the Option III trip setpoint is too high. GE issued a Part 21 Notification in GE 10 CFR Part 21 Notification, *Stability Reload Licensing Calculations Using Generic DIVOM Curve,* MFN 01-046, August 31, 2001.

To address this issue related to the generic DIVOM slope, AREVA has performed calculations for the relative change in ΔMCPR as a function of the calculated hot channel oscillation magnitude (HCOM). These calculations have been performed with the RAMONA5-FA code. This code is a coupled neutronic-thermal hydraulic three-dimensional transient model for the purpose of determining relationship between the relative change in ΔMCPR and the HCOM on a plant specific basis. This model has been developed consistent with the recommendations of the BWROG in OG04-0153-260, *Plant-Specific Regional Mode DIVOM Procedure Guideline,* June 15, 2004. The generation of the plant-specific DIVOM data with this model is consistent with the BWROG resolution of the above Part 21 notification as provided in BWROG-03047, *Resolution of Reportable Condition for Stability Reload Licensing Calculations Using Generic Regional Mode DIVOM Curve*, September 30, 2003.

The stability-based OLMCPRs were calculated using the most limiting calculated change in relative ΔMCPR for a given oscillation magnitude. The reload validation calculation demonstrated that reactor stability does not produce the limiting OLMCPR as long as the selected OPRM setpoint produces values for OLMCPR(SS) and OLMCPR(2PT) that are less than the corresponding acceptance criteria. The setpoints provided in Table 4.2 support the EOOS operating conditions provided in Table 1.1.

Table 4.1 Core Composition

Fuel Description		Cycle Loaded	Number of Assemblies
ATRIUM-10	A10-3813B-13GV80	12	22
ATRIUM-10	A10-4077B-15GV80	12	30
ATRIUM-10	A10-4088B-13GV80	12	43
ATRIUM-10	A10-4171B-14GV80-FCB	13	63
ATRIUM-10	A10-4163B-16GV80-FCB	13	168
ATRIUM-10	A10-4181B-13GV80-FCB	13	64
ATRIUM-10	A10-4218B-15GV80-FCC	14	218
ATRIUM-10	A10-4218B-13GV80-FCC	14	92
ATRIUM-10	A10-3757B-10GV80-FCC	14	64

Table 4.2 OPRM Setpoint Versus Stability-Based MCPR Operating Limits

BOC to FFTR / Coastdown		
OPRM Setpoint Δ(SP)	OLMCPR (SS)	OLMCPR (2PT)
1.05	1.23	1.15
1.06	1.24	1.16
1.07	1.25	1.17
1.08	1.26	1.18
1.09	1.26	1.18
1.10	1.28	1.20
1.11	1.30	1.22
1.12	1.32	1.24
1.13	1.34	1.26
1.14	1.36	1.28
1.15	1.39	1.30
Acceptance Criteria	Off-rated OLMCPR @45% Flow	Rated Power OLMCPR as described in Section 5

Table 4.3 Neutronic Design Values

Number of fuel assemblies	764
Rated thermal power,* MWt	3952
Rated core flow,* Mlbm/hr	102.5
Fuel channel dimensions	
Corner thickness, inch	0.100
Reduced thickness, inch	0.075
Fuel assembly pitch, inch	6.0
Wide water gap thickness, inch	0.630
Narrow water gap thickness, inch	0.414
Control Blades†	
Total span, inch	9.810
Total support span, inch	1.580
Total thickness, inch	0.312
Total face-to-face internal dimension, inch	0.200
B_4C rod absorber	
Number of rods	21
Rod diameter ID/OD, inch	0.138 / 0.188
Theoretical density of B_4C, %	70

* Statepoint parameters for individual solutions are based on consistent heat balance calculations for the core power and flow prescribed for the condition being modeled.

† The control rod data represent the Duralife-100D/BWR-4 blade type.

	31	33	35	37	39	41	43	45	47	49	51	53	55	57	59
30	4 0.0	1 22.2	5 0.0	2 23.2	4 0.0	2 23.2	4 0.0	2 22.7	4 0.0	2 22.7	4 0.0	1 23.4	5 0.0	5 0.0	32 40.1
28	1 23.3	5 0.0	2 24.0	4 0.0	1 22.3	4 0.0	2 23.0	5 0.0	1 22.3	4 0.0	2 21.9	6 0.0	4 0.0	3 18.4	32 34.9
26	5 0.0	2 22.2	4 0.0	2 23.2	4 0.0	1 23.5	4 0.0	2 21.2	4 0.0	2 22.3	4 0.0	3 17.7	5 0.0	6 0.0	32 40.1
24	2 23.4	4 0.0	2 22.3	5 0.0	2 22.2	4 0.0	2 23.1	4 0.0	2 22.9	4 0.0	2 23.6	6 0.0	4 0.0	5 0.0	33 39.7
22	4 0.0	1 20.9	4 0.0	2 23.1	4 0.0	1 23.2	4 0.0	2 23.6	4 0.0	2 22.9	5 0.0	3 17.8	5 0.0	1 21.1	33 37.5
20	2 23.3	4 0.0	1 20.8	4 0.0	1 23.3	4 0.0	1 21.1	4 0.0	2 23.2	4 0.0	2 24.5	6 0.0	4 0.0	6 0.0	33 38.3
18	4 0.0	2 22.4	4 0.0	2 23.1	4 0.0	1 20.9	4 0.0	2 20.2	4 0.0	2 23.2	4 0.0	3 17.9	5 0.0	3 15.8	33 40.2
16	2 23.1	5 0.0	2 22.5	4 0.0	2 23.5	4 0.0	2 22.9	4 0.0	2 24.2	6 0.0	4 0.0	6 0.0	3 17.8	31 33.5	
14	4 0.0	1 21.1	4 0.0	2 20.4	4 0.0	2 22.1	4 0.0	2 23.5	4 0.0	3 18.0	5 0.0	6 0.0	33 38.7		
12	2 22.9	4 0.0	2 20.4	4 0.0	2 23.3	4 0.0	2 22.8	6 0.0	3 18.6	5 0.0	3 17.8	32 38.2	32 34.0		
10	4 0.0	2 22.1	4 0.0	2 22.9	5 0.0	2 23.6	4 0.0	4 0.0	5 0.0	3 17.6	32 39.7				
8	1 23.0	6 0.0	3 15.9	6 0.0	3 18.4	6 0.0	3 18.1	6 0.0	6 0.0	32 39.1					
6	5 0.0	4 0.0	5 0.0	4 0.0	5 0.0	4 0.0	5 0.0	3 15.9	33 39.3	33 38.9					
4	5 0.0	3 15.8	6 0.0	5 0.0	1 22.5	6 0.0	3 16.8	33 38.1							
2	31 37.8	31 40.4	32 40.2	33 40.1	33 39.7	32 40.3	32 34.8								

Nuclear Fuel Type
BOC Exposure (GWd/MTU)

Fuel Type	Description	Cycle Loaded	No. Per Quarter core
31	A10-3813B-13GV80	12	3
32	A10-4077B-15GV80	12	10
33	A10-4088B-13GV80	12	10
1	A10-4171B-14GV80-FCB	13	16
2	A10-4163B-16GV80-FCB	13	42
3	A10-4181B-13GV80-FCB	13	16
4	A10-4218B-15GV80-FCC	14	55
5	A10-4218B-13GV80-FCC	14	23
6	A10-3757B-10GV80-FCC	14	16

Figure 4.1 Lower Right Quarter Core Layout By Fuel Type

5.0 Abnormal Operational Transients

Applicable Disposition of Events — Reference 9.5

5.1 *Analysis of Plant Transients at Rated Power Conditions* — Reference 9.6

Limiting Transients:
- Load Rejection No Bypass (LRNB)
- Turbine Trip No Bypass (TTNB)
- Feedwater Controller Failure (FWCF)
- Loss of Feedwater Heating (LFWH)†
- Control Rod Withdrawal Error (CRWE), see Section 5.5

5.1.1 NEOC Licensing Exposure

Transient	Scram Speed	Peak Neutron Flux (% Rated)	Peak Heat Flux (% Rated)	ΔCPR
LRNB*	TSSS	295	116	.30
TTNB*	TSSS	298	116	.30
FWCF*	TSSS	291	121	.33
LRNB*	NSS	273	114	.28
TTNB*	NSS	275	114	.28
FWCF*	NSS	280	119	.31
LFWH†		--	--	.09

* The results presented are based on base case operation at 100%P/105%F and are the most limiting considering earlier exposures.

† The inadvertent HPCI pump startup event (including asymmetric injection effects) has been analyzed generically for Browns Ferry and has been determined to be nonlimiting (Reference 9.5). The EPU inadvertent HPCI pump startup analysis demonstrated that the event did not reach the level 8 trip setpoint (with sufficient margin); therefore, the event does not result in a turbine trip and the resulting pressurization transient.

5.1.2 EOC Licensing Exposure

Transient	Scram Speed	Peak Neutron Flux (% Rated)	Peak Heat Flux (% Rated)	ΔCPR
LRNB*	TSSS	339	121	.31
TTNB*	TSSS	343	122	.31
FWCF*	TSSS	343	126	.33
LRNB*	NSS	324	120	.30
TTNB*	NSS	328	121	.30
FWCF*	NSS	334	125	.32
LFWH†		--	--	.09

5.1.3 FFTR/Coastdown Licensing Exposure

Transient	Scram Speed	Peak Neutron Flux (% Rated)	Peak Heat Flux (% Rated)	ΔCPR
LRNB*	TSSS	343	122	.31
TTNB*	TSSS	348	122	.31
FWCF*	TSSS	343	128	.34
LRNB*	NSS	327	121	.30
TTNB*	NSS	331	122	.30
FWCF*	NSS	338	128	.33
LFWH†		--	--	.09

* The results presented are based on base case operation at 100%P/105%F and are the most limiting considering earlier exposures.

† The inadvertent HPCI pump startup event (including asymmetric injection effects) has been analyzed generically for Browns Ferry and has been determined to be nonlimiting (Reference 9.5). The EPU inadvertent HPCI pump startup analysis demonstrated that the event did not reach the level 8 trip setpoint (with sufficient margin); therefore, the event does not result in a turbine trip and the resulting pressurization transient.

5.2 *Analysis for Reduced Flow Operation*

Reference 9.6

Limiting Transient: Slow Flow Excursion

$MCPR_f$	Tables 5.1 and 5.2 Reference 9.6 Figures 2.1 and 2.2
$LHGRFAC_f$	Table 5.3 Reference 9.6 Figure 2.3

$MCPR_f$ and $LHGRFAC_f$ results are applicable at all cycle exposures and in all EOD and EOOS scenarios presented in Table 1.1. Since the Cycle 14 core is composed of only ATRIUM-10 fuel, $MAPFAC_f$ multipliers are not required.

5.3 *Analysis for Reduced Power Operation*

Reference 9.6

Limiting Transients: Load Rejection No Bypass (LRNB)
Turbine Trip No Bypass (TTNB)
Feedwater Controller Failure (FWCF)

$MCPR_p$ Base Case and EOOS Operation	Tables 5.4 and 5.5 Reference 9.6 Sections 3.0 and 4.0
$LHGRFAC_p$ All Conditions	Table 5.6 Reference 9.6 Sections 3.0 and 4.0

Since the Cycle 14 core is composed of only ATRIUM-10 fuel, $MAPFAC_p$ multipliers are not required.

5.4 *ASME Overpressurization Analysis*

Reference 9.6

Limiting Event	MSIV Closure
Worst Single Failure	Valve Position Scram
Maximum Vessel Pressure (Lower Plenum)	1346 psig
Maximum Steam Dome Pressure	1318 psig

5.5 *Control Rod Withdrawal Error*

The CRWE event was analyzed assuming no xenon and 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 the analytical RBM high power setpoint values of 107% to 117% and all intermediate and lower power setpoint values, the $MCPR_p$ values bound the CRWE MCPR values. The MCPR values are based on an SLMCPR of 1.09. For other values of SLMCPR the CRWE MCPR can be adjusted by the difference in the SLMCPR and 1.09. AREVA analyses show that the filtered RBM setpoint reductions given in Reference 9.15 are supported.

The ATRIUM-10 fuel design meets the 1% plastic strain and centerline melt criteria by not exceeding the protection against power transient (PAPT) LHGR limit during the event (References 9.11, 9.12, and 9.16).

The recommended operability requirements based on the generic unblocked CRWE results are shown in Table 5.8 based upon the SLMCPR values of Section 3.3. For other values of SLMCPR, the MCPR in Table 5.8 can be adjusted by the ratio of the SLMCPR values. For Cycle 14, the CRWE results at all power levels are bounded by the $MCPR_p$ values given in Tables 5.4 - 5.5.

5.6 *Fuel Loading Error (Infrequent Event)*

As described in the AREVA topical report XN-NF-80-19(P)(A) Volume 4 Revision 1, the Fuel Loading error is characterized as an Infrequent Event and the acceptance criteria is that the offsite dose consequences due to the event shall not exceed a small fraction of the 10 CFR 50.67 limits.

5.6.1 Mislocated Fuel Assembly

AREVA has performed a bounding fuel mislocation error analysis and has demonstrated continued applicability of the bounding results. This analysis evaluated the impact of a mislocated assembly against potential fuel rod failure mechanisms due to increased LHGR and reduced CPR. Based on these analyses, the offsite dose criteria (a small fraction of 10 CFR 50.67) is conservatively satisfied. Since no rod LHGR would exceed the transient LHGR limit, and since less than 0.1% of the fuel rods are expected to experience boiling transition which could result in a dryout induced failure, a dose consequence evaluation is not necessary.

5.6.2 Misoriented Fuel Bundle

AREVA has performed a bounding fuel assembly misorientation analysis. The analysis was performed assuming that the limiting assembly was loaded in the worst orientation (rotated 180°) while producing sufficient power to be on the MCPR limit if it had been oriented correctly. The analyses demonstrate that the small fraction of 10 CFR 50.67 offsite dose criteria is conservatively satisfied. A dose consequence evaluation is not necessary since less than 0.1%

of the fuel rods are expected to experience boiling transition and the change in LHGR for the misoriented assembly remains below the transient LHGR limit.

5.7 *Determination of Thermal Margins*

The results of the analyses presented in Sections 5.1–5.3 and 5.5 are used for the determination of the MCPR and LHGR operating limits. Section 5.1 provides the results of analyses at rated conditions. Section 5.2 provides for the determination of the $MCPR_f$ and $LHGR_f$ limits at reduced flow ($MCPR_f$, Tables 5.1–5.2, $LHGRFAC_f$, Table 5.3). Section 5.3 provides for the determination of the $MCPR_p$ limits and $LHGRFAC_p$ at conditions of reduced power (Tables 5.4–5.6). Exposure dependent limits are presented for base case operation and the EOOS conditions presented in Table 1.1. $MCPR_p$ limits for single-loop operation (SLO) will be 0.02 higher than those for two-loop because the SLO SLMCPR is 0.02 higher.

TLO $MCPR_f$ limits and $LHGRFAC_f$ multipliers are applicable for SLO without any adjustment. The flow-dependent limits are based on a slow flow excursion of two recirculation loops for TLO, which is conservative relative to a single recirculation loop excursion that could occur in SLO.

For SLO operation, the MAPLHGR multiplier listed in Section 7.2.1 is applied.

Table 5.1 Flow-Dependent MCPR Limits for Maximum Flow of 102.5% of Rated Flow

Core Flow (% of rated)	$MCPR_f$ ATRIUM-10
30	1.46
72	1.28
102.5	1.28

Table 5.2 Flow-Dependent MCPR Limits for Maximum Flow of 107% of Rated Flow

Core Flow (% of rated)	$MCPR_f$ ATRIUM-10
30	1.49
78	1.28
107	1.28

Table 5.3 Flow-Dependent $LHGRFAC_f$ Multipliers for Maximum Flow of 102.5% and 107% of Rated Flow

Maximum Core Flow of 102.5% Rated		Maximum Core Flow of 107% Rated	
Core Flow (% of rated)	$LHGRFAC_f$	Core Flow (% of rated)	$LHGRFAC_f$
30	0.94	30	0.92
42.8	1.00	47.1	1.00
102.5	1.00	107	1.00

Table 5.4 MCPR$_p$ Limits for NSS Insertion Times*

Operating Condition	Power (% of rated)	BOC to NEOC	BOC to EOC	BOC to End of COAST
Base case	100.0	1.40	1.41	1.42
	60.0	1.60	1.60	1.64
	55.0	1.62	1.62	1.68
	50.0	1.67	1.67	1.73
	50.0	1.82	1.82	1.82
	40.0	1.90	1.90	1.90
	26.0	2.21	2.21	2.31
	26.0 at > 50%F	2.63	2.63	2.72
	23.0 at > 50%F	2.78	2.78	2.90
	26.0 at ≤ 50%F	2.49	2.49	2.58
	23.0 at ≤ 50%F	2.62	2.62	2.72
TBVOOS	100.0	1.43	1.44	1.45
	60.0	1.63	1.63	1.65
	55.0	1.65	1.65	1.70
	50.0	1.69	1.69	1.75
	50.0	1.82	1.82	1.82
	40.0	1.90	1.90	1.90
	26.0	2.23	2.23	2.33
	26.0 at > 50%F	3.12	3.12	3.20
	23.0 at > 50%F	3.39	3.39	3.48
	26.0 at ≤ 50%F	2.65	2.65	2.72
	23.0 at ≤ 50%F	2.88	2.88	2.96
EOC-RPT-OOS	100.0	1.40	1.41	1.42
	60.0	1.60	1.60	1.64
	55.0	1.62	1.62	1.68
	50.0	1.67	1.67	1.73
	50.0	1.82	1.82	1.82
	40.0	1.90	1.90	1.90
	26.0	2.21	2.21	2.31
	26.0 at > 50%F	2.63	2.63	2.72
	23.0 at > 50%F	2.78	2.78	2.90
	26.0 at ≤ 50%F	2.49	2.49	2.58
	23.0 at ≤ 50%F	2.62	2.62	2.72
FHOOS	100.0	1.42	1.42	---
	60.0	1.64	1.64	---
	55.0	1.68	1.68	---
	50.0	1.73	1.73	---
	50.0	1.82	1.82	---
	40.0	1.90	1.90	---
	26.0	2.31	2.31	---
	26.0 at > 50%F	2.72	2.72	---
	23.0 at > 50%F	2.90	2.90	---
	26.0 at ≤ 50%F	2.58	2.58	---
	23.0 at ≤ 50%F	2.72	2.72	---

* Limits support operation with any combination of 1 MSRVOOS, up to 2 TIPOOS (or the equivalent number of TIP channels), and up to 50% of the LPRMs out-of-service. For single-loop operation, MCPR$_p$ limits will be 0.02 higher.

FHOOS limits are not provided for BOC to End of COAST since the feewater temperature for FHOOS was assumed to be the same as FFTR. The thermal limit at BOC to End of COAST was developed to bound the corresponding earlier exposure FHOOS limit.

A step change in PLUOOS limits at 50% power is not supported since at 50% and below the LRNB with or without PLUOOS is the same event.

Table 5.4 MCPR$_p$ Limits for NSS Insertion Times
(Continued)

Operating Condition	Power (% of rated)	BOC to NEOC	BOC to EOC	BOC to End of COAST
PLUOOS	100.0	1.40	1.41	1.42
	60.0	1.60	1.60	1.64
	55.0	1.79	1.79	1.79
	50.0	---	---	---
	50.0	1.82	1.82	1.82
	40.0	1.90	1.90	1.90
	26.0	2.21	2.21	2.31
	26.0 at > 50%F	2.63	2.63	2.72
	23.0 at > 50%F	2.78	2.78	2.90
	26.0 at ≤ 50%F	2.49	2.49	2.58
	23.0 at ≤ 50%F	2.62	2.62	2.72
EOC-RPT-OOS TBVOOS	100.0	1.43	1.44	1.45
	60.0	1.63	1.63	1.65
	55.0	1.65	1.65	1.70
	50.0	1.69	1.69	1.75
	50.0	1.82	1.82	1.82
	40.0	1.90	1.90	1.90
	26.0	2.23	2.23	2.33
	26.0 at > 50%F	3.12	3.12	3.20
	23.0 at > 50%F	3.39	3.39	3.48
	26.0 at ≤ 50%F	2.65	2.65	2.72
	23.0 at ≤ 50%F	2.88	2.88	2.96
EOC-RPT-OOS FHOOS	100.0	1.42	1.42	---
	60.0	1.64	1.64	---
	55.0	1.68	1.68	---
	50.0	1.73	1.73	---
	50.0	1.82	1.82	---
	40.0	1.90	1.90	---
	26.0	2.31	2.31	---
	26.0 at > 50%F	2.72	2.72	---
	23.0 at > 50%F	2.90	2.90	---
	26.0 at ≤ 50%F	2.58	2.58	---
	23.0 at ≤ 50%F	2.72	2.72	---
EOC-RPT-OOS PLUOOS	100.0	1.40	1.41	1.42
	60.0	1.60	1.60	1.64
	55.0	1.79	1.79	1.79
	50.0	---	---	---
	50.0	1.82	1.82	1.82
	40.0	1.90	1.90	1.90
	26.0	2.21	2.21	2.31
	26.0 at > 50%F	2.63	2.63	2.72
	23.0 at > 50%F	2.78	2.78	2.90
	26.0 at ≤ 50%F	2.49	2.49	2.58
	23.0 at ≤ 50%F	2.62	2.62	2.72

Table 5.4 MCPR$_p$ Limits for NSS Insertion Times
(Continued)

Operating Condition	Power (% of rated)	BOC to NEOC	BOC to EOC	BOC to End of COAST
TBVOOS FHOOS	100.0	1.45	1.45	---
	60.0	1.65	1.65	---
	55.0	1.70	1.70	---
	50.0	1.75	1.75	---
	50.0	1.82	1.82	---
	40.0	1.90	1.90	---
	26.0	2.33	2.33	---
	26.0 at > 50%F	3.20	3.20	---
	23.0 at > 50%F	3.48	3.48	---
	26.0 at ≤ 50%F	2.72	2.72	---
	23.0 at ≤ 50%F	2.96	2.96	---
TBVOOS PLUOOS	100.0	1.43	1.44	1.45
	60.0	1.63	1.63	1.65
	55.0	1.79	1.79	1.79
	50.0	---	---	---
	50.0	1.82	1.82	1.82
	40.0	1.90	1.90	1.90
	26.0	2.23	2.23	2.33
	26.0 at > 50%F	3.12	3.12	3.20
	23.0 at > 50%F	3.39	3.39	3.48
	26.0 at ≤ 50%F	2.65	2.65	2.72
	23.0 at ≤ 50%F	2.88	2.88	2.96
FHOOS PLUOOS	100.0	1.42	1.42	---
	60.0	1.64	1.64	---
	55.0	1.79	1.79	---
	50.0	---	---	---
	50.0	1.82	1.82	---
	40.0	1.90	1.90	---
	26.0	2.31	2.31	---
	26.0 at > 50%F	2.72	2.72	---
	23.0 at > 50%F	2.90	2.90	---
	26.0 at ≤ 50%F	2.58	2.58	---
	23.0 at ≤ 50%F	2.72	2.72	---
EOC-RPT-OOS TBVOOS FHOOS	100.0	1.45	1.45	---
	60.0	1.65	1.65	---
	55.0	1.70	1.70	---
	50.0	1.75	1.75	---
	50.0	1.82	1.82	---
	40.0	1.90	1.90	---
	26.0	2.33	2.33	---
	26.0 at > 50%F	3.20	3.20	---
	23.0 at > 50%F	3.48	3.48	---
	26.0 at ≤ 50%F	2.72	2.72	---
	23.0 at ≤ 50%F	2.96	2.96	---

Table 5.4 MCPR$_p$ Limits for NSS Insertion Times
(Continued)

Operating Condition	Power (% of rated)	BOC to NEOC	BOC to EOC	BOC to End of COAST
EOC-RPT-OOS TBVOOS PLUOOS	100.0	1.43	1.44	1.45
	60.0	1.63	1.63	1.65
	55.0	1.79	1.79	1.79
	50.0	---	---	---
	50.0	1.82	1.82	1.82
	40.0	1.90	1.90	1.90
	26.0	2.23	2.23	2.33
	26.0 at > 50%F	3.12	3.12	3.20
	23.0 at > 50%F	3.39	3.39	3.48
	26.0 at ≤ 50%F	2.65	2.65	2.72
	23.0 at ≤ 50%F	2.88	2.88	2.96
EOC-RPT-OOS FHOOS PLUOOS	100.0	1.42	1.42	---
	60.0	1.64	1.64	---
	55.0	1.79	1.79	---
	50.0	---	---	---
	50.0	1.82	1.82	---
	40.0	1.90	1.90	---
	26.0	2.31	2.31	---
	26.0 at > 50%F	2.72	2.72	---
	23.0 at > 50%F	2.90	2.90	---
	26.0 at ≤ 50%F	2.58	2.58	---
	23.0 at ≤ 50%F	2.72	2.72	---
TBVOOS FHOOS PLUOOS	100.0	1.45	1.45	---
	60.0	1.65	1.65	---
	55.0	1.79	1.79	---
	50.0	---	---	---
	50.0	1.82	1.82	---
	40.0	1.90	1.90	---
	26.0	2.33	2.33	---
	26.0 at > 50%F	3.20	3.20	---
	23.0 at > 50%F	3.48	3.48	---
	26.0 at ≤ 50%F	2.72	2.72	---
	23.0 at ≤ 50%F	2.96	2.96	---
EOC-RPT-OOS TBVOOS FHOOS PLUOOS	100.0	1.45	1.45	---
	60.0	1.65	1.65	---
	55.0	1.79	1.79	---
	50.0	---	---	---
	50.0	1.82	1.82	---
	40.0	1.90	1.90	---
	26.0	2.33	2.33	---
	26.0 at > 50%F	3.20	3.20	---
	23.0 at > 50%F	3.48	3.48	---
	26.0 at ≤ 50%F	2.72	2.72	---
	23.0 at ≤ 50%F	2.96	2.96	---

Table 5.5 MCPR$_p$ Limits for TSSS Insertion Times*

Operating Condition	Power (% of rated)	BOC to NEOC	BOC to EOC	BOC to End of COAST
Base case	100.0	1.42	1.42	1.44
	60.0	1.62	1.62	1.66
	55.0	1.65	1.65	1.70
	50.0	1.69	1.69	1.75
	50.0	1.83	1.83	1.83
	40.0	1.91	1.91	1.91
	26.0	2.23	2.23	2.33
	26.0 at > 50%F	2.63	2.63	2.72
	23.0 at > 50%F	2.78	2.78	2.90
	26.0 at ≤ 50%F	2.49	2.49	2.58
	23.0 at ≤ 50%F	2.62	2.62	2.72
TBVOOS	100.0	1.45	1.46	1.47
	60.0	1.65	1.65	1.68
	55.0	1.67	1.67	1.72
	50.0	1.71	1.71	1.77
	50.0	1.83	1.83	1.83
	40.0	1.91	1.91	1.91
	26.0	2.25	2.25	2.35
	26.0 at > 50%F	3.12	3.12	3.20
	23.0 at > 50%F	3.39	3.39	3.48
	26.0 at ≤ 50%F	2.65	2.65	2.72
	23.0 at ≤ 50%F	2.88	2.88	2.96
EOC-RPT-OOS	100.0	1.42	1.42	1.44
	60.0	1.62	1.62	1.66
	55.0	1.65	1.65	1.70
	50.0	1.69	1.69	1.75
	50.0	1.83	1.83	1.83
	40.0	1.91	1.91	1.91
	26.0	2.23	2.23	2.33
	26.0 at > 50%F	2.63	2.63	2.72
	23.0 at > 50%F	2.78	2.78	2.90
	26.0 at ≤ 50%F	2.49	2.49	2.58
	23.0 at ≤ 50%F	2.62	2.62	2.72
FHOOS	100.0	1.44	1.44	---
	60.0	1.66	1.66	---
	55.0	1.70	1.70	---
	50.0	1.75	1.75	---
	50.0	1.83	1.83	---
	40.0	1.91	1.91	---
	26.0	2.33	2.33	---
	26.0 at > 50%F	2.72	2.72	---
	23.0 at > 50%F	2.90	2.90	---
	26.0 at ≤ 50%F	2.58	2.58	---
	23.0 at ≤ 50%F	2.72	2.72	---

* Limits support operation with any combination of 1 MSRVOOS, up to 2 TIPOOS (or the equivalent number of TIP channels), and up to 50% of the LPRMs out-of-service. For single-loop operation, MCPR$_p$ limits will be 0.02 higher.

FHOOS limits are not provided for BOC to End of COAST since the feewater temperature for FHOOS was assumed to be the same as FFTR. The thermal limit at BOC to End of COAST was developed to bound the corresponding earlier exposure FHOOS limit.

A step change in PLUOOS limits at 50% power is not supported since at 50% and below the LRNB with or without PLUOOS is the same event.

Table 5.5 $MCPR_p$ Limits for TSSS Insertion Times
(Continued)

Operating Condition	Power (% of rated)	BOC to NEOC	BOC to EOC	BOC to End of Coast
PLUOOS	100.0	1.42	1.42	1.44
	60.0	1.62	1.62	1.66
	55.0	1.80	1.80	1.80
	50.0	---	---	---
	50.0	1.83	1.83	1.83
	40.0	1.91	1.91	1.91
	26.0	2.23	2.23	2.33
	26.0 at > 50%F	2.63	2.63	2.72
	23.0 at > 50%F	2.78	2.78	2.90
	26.0 at ≤ 50%F	2.49	2.49	2.58
	23.0 at ≤ 50%F	2.62	2.62	2.72
EOC-RPT-OOS TBVOOS	100.0	1.45	1.47	1.48
	60.0	1.65	1.65	1.68
	55.0	1.67	1.67	1.72
	50.0	1.71	1.71	1.77
	50.0	1.83	1.83	1.83
	40.0	1.91	1.91	1.91
	26.0	2.25	2.25	2.35
	26.0 at > 50%F	3.12	3.12	3.20
	23.0 at > 50%F	3.39	3.39	3.48
	26.0 at ≤ 50%F	2.65	2.65	2.72
	23.0 at ≤ 50%F	2.88	2.88	2.96
EOC-RPT-OOS FHOOS	100.0	1.44	1.44	---
	60.0	1.66	1.66	---
	55.0	1.70	1.70	---
	50.0	1.75	1.75	---
	50.0	1.83	1.83	---
	40.0	1.91	1.91	---
	26.0	2.33	2.33	---
	26.0 at > 50%F	2.72	2.72	---
	23.0 at > 50%F	2.90	2.90	---
	26.0 at ≤ 50%F	2.58	2.58	---
	23.0 at ≤ 50%F	2.72	2.72	---
EOC-RPT-OOS PLUOOS	100.0	1.42	1.42	1.44
	60.0	1.62	1.62	1.66
	55.0	1.80	1.80	1.80
	50.0	---	---	---
	50.0	1.83	1.83	1.83
	40.0	1.91	1.91	1.91
	26.0	2.23	2.23	2.33
	26.0 at > 50%F	2.63	2.63	2.72
	23.0 at > 50%F	2.78	2.78	2.90
	26.0 at ≤ 50%F	2.49	2.49	2.58
	23.0 at ≤ 50%F	2.62	2.62	2.72

Table 5.5 $MCPR_p$ Limits for TSSS Insertion Times
(Continued)

Operating Condition	Power (% of rated)	BOC to NEOC	BOC to EOC	BOC to End of Coast
TBVOOS FHOOS	100.0	1.47	1.47	---
	60.0	1.68	1.68	---
	55.0	1.72	1.72	---
	50.0	1.77	1.77	---
	50.0	1.83	1.83	---
	40.0	1.91	1.91	---
	26.0	2.35	2.35	---
	26.0 at > 50%F	3.20	3.20	---
	23.0 at > 50%F	3.48	3.48	---
	26.0 at ≤ 50%F	2.72	2.72	---
	23.0 at ≤ 50%F	2.96	2.96	---
TBVOOS PLUOOS	100.0	1.45	1.46	1.47
	60.0	1.65	1.65	1.68
	55.0	1.80	1.80	1.80
	50.0	---	---	---
	50.0	1.83	1.83	1.83
	40.0	1.91	1.91	1.91
	26.0	2.25	2.25	2.35
	26.0 at > 50%F	3.12	3.12	3.20
	23.0 at > 50%F	3.39	3.39	3.48
	26.0 at ≤ 50%F	2.65	2.65	2.72
	23.0 at ≤ 50%F	2.88	2.88	2.96
FHOOS PLUOOS	100.0	1.44	1.44	---
	60.0	1.66	1.66	---
	55.0	1.80	1.80	---
	50.0	---	---	---
	50.0	1.83	1.83	---
	40.0	1.91	1.91	---
	26.0	2.33	2.33	---
	26.0 at > 50%F	2.72	2.72	---
	23.0 at > 50%F	2.90	2.90	---
	26.0 at ≤ 50%F	2.58	2.58	---
	23.0 at ≤ 50%F	2.72	2.72	---
EOC-RPT-OOS TBVOOS FHOOS	100.0	1.47	1.47	---
	60.0	1.68	1.68	---
	55.0	1.72	1.72	---
	50.0	1.77	1.77	---
	50.0	1.83	1.83	---
	40.0	1.91	1.91	---
	26.0	2.35	2.35	---
	26.0 at > 50%F	3.20	3.20	---
	23.0 at > 50%F	3.48	3.48	---
	26.0 at ≤ 50%F	2.72	2.72	---
	23.0 at ≤ 50%F	2.96	2.96	---

Table 5.5 $MCPR_p$ Limits for TSSS Insertion Times
(Continued)

Operating Condition	Power (% of rated)	BOC to NEOC	BOC to EOC	BOC to End of Coast
EOC-RPT-OOS TBVOOS PLUOOS	100.0	1.45	1.47	1.48
	60.0	1.65	1.65	1.68
	55.0	1.80	1.80	1.80
	50.0	---	---	---
	50.0	1.83	1.83	1.83
	40.0	1.91	1.91	1.91
	26.0	2.25	2.25	2.35
	26.0 at > 50%F	3.12	3.12	3.20
	23.0 at > 50%F	3.39	3.39	3.48
	26.0 at ≤ 50%F	2.65	2.65	2.72
	23.0 at ≤ 50%F	2.88	2.88	2.96
EOC-RPT-OOS FHOOS PLUOOS	100.0	1.44	1.44	---
	60.0	1.66	1.66	---
	55.0	1.80	1.80	---
	50.0	---	---	---
	50.0	1.83	1.83	---
	40.0	1.91	1.91	---
	26.0	2.33	2.33	---
	26.0 at > 50%F	2.72	2.72	---
	23.0 at > 50%F	2.90	2.90	---
	26.0 at ≤ 50%F	2.58	2.58	---
	23.0 at ≤ 50%F	2.72	2.72	---
TBVOOS FHOOS PLUOOS	100.0	1.47	1.47	---
	60.0	1.68	1.68	---
	55.0	1.80	1.80	---
	50.0	---	---	---
	50.0	1.83	1.83	---
	40.0	1.91	1.91	---
	26.0	2.35	2.35	---
	26.0 at > 50%F	3.20	3.20	---
	23.0 at > 50%F	3.48	3.48	---
	26.0 at ≤ 50%F	2.72	2.72	---
	23.0 at ≤ 50%F	2.96	2.96	---
EOC-RPT-OOS TBVOOS FHOOS PLUOOS	100.0	1.47	1.47	---
	60.0	1.68	1.68	---
	55.0	1.80	1.80	---
	50.0	---	---	---
	50.0	1.83	1.83	---
	40.0	1.91	1.91	---
	26.0	2.35	2.35	---
	26.0 at > 50%F	3.20	3.20	---
	23.0 at > 50%F	3.48	3.48	---
	26.0 at ≤ 50%F	2.72	2.72	---
	23.0 at ≤ 50%F	2.96	2.96	---

Table 5.6 LHGRFAC$_p$ Multipliers
NSS/TSSS Insertion Times
All Exposures*

Operating Condition	Power (% of rated)	ATRIUM-10 LHGRFAC$_p$
Base case operation†	100 26 26 at > 50%F 23 at > 50%F 26 at ≤ 50%F 23 at ≤ 50%F	1.00 0.64 0.53 0.51 0.53 0.53
EOOS with TBV in-service†	100 26 26 at > 50%F 23 at > 50%F 26 at ≤ 50%F 23 at ≤ 50%F	1.00 0.64 0.53 0.51 0.53 0.53
EOOS with TBVOOS‡	100 26 26 at > 50%F 23 at > 50%F 26 at ≤ 50%F 23 at ≤ 50%F	1.00 0.63 0.46 0.42 0.53 0.52

* Limits support operation with any combination of 1 MSRVOOS, up to 2 TIPOOS (or the equivalent number of TIP channels), and up to 50% of the LPRMs out-of-service. Base case supports single-loop operation.

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

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

Table 5.7 Control Rod Withdrawal Error MCPR versus RBM Setpoint Results (for Rated Power and 1.09 SLMCPR)

Analytical RBM Setpoint (w/o filter) (%)	CRWE MCPR
107	1.27
111	1.32
114	1.35
117	1.35

Table 5.8 RBM Setpoint Applicability

Thermal Power (% of rated)	Applicable MCPR*	
≥ 27% and < 90%	< 1.74	TLO
	< 1.77	SLO
≥ 90%	< 1.43	TLO†

* The MCPR values shown correspond to an SLMCPR of 1.09 for TLO and 1.11 for SLO.

† Greater than 90% rated power is not attainable in SLO.

6.0 Postulated Accidents

6.1 *Loss-of-Coolant Accident*

6.1.1 Break Location Spectrum

Reference 9.7

6.1.2 Break Size Spectrum

Reference 9.7

6.1.3 MAPLHGR Analyses

The MAPLHGR limits presented in Reference 9.8 remain valid for ATRIUM-10 fuel.

Limiting Break: 0.5 ft^2 split
Recirculation Pump Discharge Line
Battery (DC) power

Based on the PCT results in Reference 9.8 and subsequent evaluations to provide 10 CFR 50.46 reporting estimates (Reference 9.10), the current licensing PCT is provided below. The MCPR value used in the LOCA analyses is less than the rated power MCPR limits presented in Section 5.0.

Initial PCT (°F) (Reference 9.8)	2007
10 CFR 50.46 Estimates net cumulative value (°F) (Reference 9.10)	- 5
Current Licensing PCT (°F)	2002

The peak local metal-water reaction for the limiting PCT lattice design is 1.71%. The maximum core wide metal-water reaction (for hydrogen generation) for a full ATRIUM-10 core is <1.0%.

The PCT for Cycle 14 ATRIUM-10 reload fuel was calculated to be 1972°F; therefore, in terms of PCT, the limiting neutronic design used in Reference 9.8 remains bounding. The peak local metal-water reaction and total core wide metal-water reaction were calculated to be 1.63% and <1%, respectively. When compared to the acceptance criteria of less than 17% local cladding oxidation thickness, the local metal-water reaction result remains acceptable.

The plant parameters for the LOCA analysis (Reference 9.7) bound the cycle-specific plant parameters documented in Reference 9.13. The LOCA analysis and results support the EOD and EOOS conditions listed in Table 1.1. Note that the following EOOS conditions have no direct influence on the LOCA events: TBVOOS, EOC-RPT-OOS, PLUOOS, and TIPOOS/LPRM out-of-service.

6.2 *Control Rod Drop Accident*

Browns Ferry Unit 3 uses a banked position withdrawal sequence (BPWS) including reduced notch worth (RNW) rod pulls to limit high worth control rod movements. A CRDA evaluation was performed for both A and B sequence startups consistent with the withdrawal sequence specified by TVA.

The CRDA analysis demonstrates that the maximum deposited fuel rod enthalpy is less than the NRC limit of 280 cal/g (fuel dispersal) and that the estimated number of fuel rods that exceed the fuel damage threshold of 170 cal/g is less than the number of failed rods (850 rods) assumed in the Browns Ferry UFSAR radiological assessment. The inputs to the deposited enthalpy calculation are determined on a cycle specific basis using the methods described in Reference 8.5. Key results from the CRDA analysis are summarized below:

Maximum dropped control rod worth, mk	11.3
Core average Doppler coefficient, $\Delta k/k/^{\circ}F$	-10.0×10^{-6}
Effective delayed neutron fraction	0.0052
Four-bundle local peaking factor	1.39
Maximum deposited fuel rod enthalpy, cal/g	210.2
Maximum number of rods exceeding 170 cal/g	182

6.4 *Fuel and Equipment Handling Accident*

The fuel handling accident radiological analysis implementing the alternative source term (AST) as approved in Reference 9.17 was performed with consideration of ATRIUM-10 core source terms. The number of failed fuel rods for the ATRIUM-10 fuel as previously provided to TVA in Reference 9.18 for use in the AST analysis is unchanged. No other aspect of utilizing the ATRIUM-10 fuel affects the current analysis; therefore, the AST analysis remains bounding for the AREVA ATRIUM-10 fuel.

7.0 Technical Specifications

7.1 *Limiting Safety System Settings*

7.1.1 MCPR Fuel Cladding Integrity Safety Limit

MCPR Safety Limit (all fuel) - two-loop operation 1.09*

MCPR Safety Limit (all fuel) - single-loop operation 1.11*

7.1.2 Steam Dome Pressure Safety Limit

Pressure Safety Limit 1325 psig

7.2 *Limiting Conditions for Operation*

7.2.1 Average Planar Linear Heat Generation Rate† — Reference 9.8

MAPLHGR Limits	
Average Planar Exposure (GWd/MTU)	MAPLHGR (kW/ft)
0.0	12.5
15.0	12.5
67.0‡	7.3

Single-Loop Operation MAPLHGR Multiplier for ATRIUM-10 Fuel is 0.85. — Reference 9.8

7.2.2 Minimum Critical Power Ratio

Flow-Dependent MCPR Limits: Tables 5.1 and 5.2

Exposure-Dependent $MCPR_p$ Limits Tables 5.4 and 5.5

* Includes the effects of channel bow, 2 TIPOOS or the equivalent number of TIP channels (per operating requirements defined in Reference 9.6 Section 3.2), a 2500 EFPH LPRM calibration interval, and up to 50% of the LPRMs out-of-service.

† Limits are applicable for all of the EOOS scenarios presented in Table 1.1. For SLO operation, the MAPLHGR multiplier listed in Section 7.2.1 is applied.

‡ Refer to References 9.11, 9.12, and 9.16 for the maximum licensing exposures.

7.2.3 Linear Heat Generation Rate

References 9.11, 9.12 and 9.16

Steady-State LHGR Limits	
Pellet Exposure (GWd/MTU)	LHGR (kW/ft)
0.0	13.4
18.9	13.4
74.4*	7.1

The PAPT LHGR curves are identified in References 9.11, 9.12 and 9.16. The $LHGRFAC_f$ and $LHGRFAC_p$ multipliers are applied directly to the steady-state LHGR limits at reduced power and reduced flow to ensure the PAPT LHGR limits are not violated during an AOT.

LHGRFAC Multipliers for Off-Rated Conditions:

$LHGRFAC_f$	Table 5.3
$LHGRFAC_p$	Table 5.6

* Refer to References 9.11, 9.12, and 9.16 for the maximum licensing exposures.

8.0 Methodology References

See XN-NF-80-19(P)(A) Volume 4 Revision 1 for a complete bibliography.

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

8.2 ANF-524(P)(A) Revision 2 and Supplements 1 and 2, *ANF Critical Power Methodology for Boiling Water Reactors*, Advanced Nuclear Fuels Corporation, November 1990.

8.3 EMF-2209(P)(A) Revision 2, *SPCB Critical Power Correlation*, Framatome ANP, September 2003.

8.4 EMF-2245(P)(A) Revision 0, *Application of Siemens Power Corporation's Critical Power Correlations to Co-Resident Fuel*, Siemens Power Corporation, August 2000.

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

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

8.7 ANF-89-98(P)(A) Revision 1 and Supplement 1, *Generic Mechanical Design Criteria for BWR Fuel Designs,* Advanced Nuclear Fuels Corporation, May 1995.

9.0 Additional References

9.1 EMF-3218(P) Revision 0, *Browns Ferry Unit 3 Thermal-Hydraulic Design Report for ATRIUM™-10 Fuel Assemblies,* Framatome ANP, September 2005.

9.2 ANP-2617(P) Revision 1, *Nuclear Fuel Design Report Browns Ferry Unit 3 Fabrication Batch BFE3-14 ATRIUM™-10 Fuel*, AREVA NP, May 2007.

9.3 ANP-2626(P) Revision 0, *Browns Ferry Unit 3 Cycle 14 Fuel Cycle Design,* AREVA NP, May 2007.

9.4 EMF-2939(P) Revision 0, *Browns Ferry Nuclear Plant Spent Fuel Storage Pool Criticality Safety Analysis for ATRIUM™-10 Fuel,* Framatome ANP, August 2003.

9.5 Letter, A.W. Will (AREVA) to G. C. Storey (TVA), "Disposition of Events for Extended Power Uprate at Browns Ferry Units 2 and 3," AWW:06:065, May 1, 2006.

9.6 ANP-2630(P) Revision 0, *Browns Ferry Unit 3 Cycle 14 Plant Transient Analysis,* AREVA NP, May 2007.

9.7 EMF-2950(P) Revision 1, *Browns Ferry Units 1, 2, and 3 Extended Power Uprate LOCA Break Spectrum Analysis,* Framatome ANP, April 2004.

9.8 EMF-3145(P) Revision 0, *Browns Ferry Units 1, 2, and 3 Extended Power Uprate LOCA-ECCS Analysis MAPLHGR Limit for ATRIUM™-10 Fuel,* Framatome ANP, December 2004.

9.9 NEDO-32465-A, Licensing Topical Report, *Reactor Stability Detect and Suppress Solutions Licensing Basis Methodology for Reload Applications,* GE Nuclear Energy, August 1996.

9.10 Letter, T.A. Galioto (AREVA) to G.C. Storey (TVA), "10 CFR 50.46 PCT Reporting for BFN Units 2 and 3," TAG:05:056, June 30, 2005.

9.11 EMF-2971(P) Revision 1, *Mechanical and Thermal-Hydraulic Design Report for Browns Ferry Unit 3 Batches BFC-1and BFC-1A ATRIUM-10 Fuel Assemblies,* Framatome ANP, January 2004.

9.12 EMF-3213(P) Revision 0, *Mechanical Design Report for Browns Ferry Unit 3 Reload BFE3-13 ATRIUM-10 Fuel Assemblies,* Framatome ANP, September 2005.

9.13 ANP-2589(P) Revision 0, *Browns Ferry Unit 3 Cycle 14 Plant Parameters Document,* AREVA NP, January 2007.

9.14 EMF-2978(P) Revision 0, *Browns Ferry Nuclear Plant New Fuel Storage Vault Criticality Safety Analysis for ATRIUM-10 Fuel,* Framatome ANP, July 2005.

9.15 NEDC-32433P, *Maximum Extended Load Line Limit and Arts Improvement Program Analyses for Browns Ferry Nuclear Plant Unit 1, 2, and 3,* GE Nuclear Energy, April 1995.

9.16 ANP-2628(P) Revision 0, *Mechanical Design Report for Browns Ferry Unit 3 Reload BFE3-14 ATRIUM-10 Fuel Assemblies,* AREVA NP, May 2007.

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

9.18 Letter, T.A. Galioto (AREVA) to J.F. Lemons (TVA), "Fuel Handling Accident Assumptions for Browns Ferry," TAG:02:012, January 23, 2002.

9.19 USNRC Certificate of Compliance for Radioactive Material Packages, Model No.: RAJ-II, USA/9309/B(U)F-96 Revision 6.

9.20 Letter, N.J. Carr (AREVA) to G.C. Storey (TVA), "Update on RAJ-II Shipping Container, Inner Container Stacking Criticality," NJC:04:052 FAB04-761, October 29, 2004.

Distribution

Controlled Distribution

OC Brown
DD Crockett
ME Garrett
JM Haun
JW Hulsman
RR Schnepp
MS Stricker
G. Touvannas
SA Tylinski

Notification List

(e-mail notification)

JS Holm
DB McBurney