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WNP-2 CYCLE 3 RELOAD ANALYSIS

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1.0 INTRODUCTION

This report summarizes the results of the analyses performed by Advanced Nuclear Fuels Corporation (ANF) in support of the Cycle 3 reload for the Supply System Nuclear Project Number 2 (WNP-2). WNP-2 is scheduled to commence Cycle 3 operation in June 1987. This report is intended to be used in conjunction with Exxon Nuclear Company (ENC) topical report XN-NF-80-19(A), Volume 4, Rev. 1, "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(A), Volume 4, Rev. 1. Appendix A of this report addresses single loop operation.

The WNP-2 Cycle 3 core will comprise a total of 764 fuel assemblies, including 148 ANF 8x8 unirradiated assemblies, 128 once irradiated ANF 8x8 assemblies, and 488 twice irradiated P8x8R assemblies fabricated by General Electric (GE). The reference core configuration is described in Section 4.2.

The design and safety analyses reported in this document were based on the design and operational assumptions in effect for WNP-2 during the previous operating cycle which encompass core flow up to 106% of the design basis value.

2.0 FUEL MECHANICAL DESIGN ANALYSIS

Applicable Fuel Design Report: Reference 9.8

The expected power history for the fuel to be irradiated during Cycle 3 of WNP-2 is bounded by the assumed power history in the fuel mechanical design analyses.

3.0 THERMAL HYDRAULIC DESIGN ANALYSIS

3.1 Design Criteria

3.1.3 Fuel Centerline Temperature

The LHGR curve in Figure 3.4 of Reference 9.8 shows that the ANF 8x8 fuel centerline temperature is protected for 120% over power. The LHGR curve in Reference 9.8 is greater than 120% above the LHGR limit curve in Reference 9.1. Therefore, fuel centerline melt is protected for all ANF 8x8 exposures within the bounds of the referenced LHGR curves.

3.2 Hydraulic Characterization

3.2.5 Bypass Flow

Calculated Bypass Flow Fraction	11.6%

3.3 MCPR Fuel Cladding Integrity Safety Limit

3.3.1 Coolant Thermodynamic Condition

Core Power	3844 MWt
Core Inlet Enthalpy	526.4 BTU/lbm
Steam Dome Pressure	1030 psia
Feedwater Temperature	420°F

3.3.2 Design Basis Radial Power Distribution

See Figure 3.1

3.3.3 Design Basis Local Power Distribuiton

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4.0 NUCLEAR DESIGN ANALYSIS

4.1 Fuel Bundle Nuclear Design Analysis

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4.2 Core Nuclear Design Analysis

4.2.1 Core Configuration — Figure 4.2

Core Exposure at EOC2 (MWD/MTM)	12,153
Core Exposure at BOC2 (MWD/MTM)	9,639
Core Exposure at EOFP3 (MWD/MTM)	15,103

4.2.2 Core Reactivity Characteristics

BOC Cold K-effective, All Rods Out	1.1257
BOC Cold K-effective, Strongest Rod Out	0.9882
Reactivity Defect/R-Value, % delta k/k	0.0
Standby Liquid Control System (SBLC) Reactivity, 660 PPM Boron, K-effective	0.9722

5.0 ANTICIPATED OPERATIONAL OCCURRENCES

Applicable Transient Analysis Report Reference 9.3

5.1 Analysis Of Plant Transients At Increased Core Flow Conditions Reference 9.3

Limiting Transient(s): Load Rejection Without Bypass (LRWB)
Feedwater Controller Failure (FWCF)
Loss of Feedwater Heating (LOFH)

Transient analyses for WNP-2 Cycle 2 anticipated operational events showed that delta CPR values at design basis conditions are bounded by delta CPR values at design basis power (104%) and increased core flow conditions (106%). Thus Cycle 3 analyses results at increased core flow conditions are conservatively applicable to rated flow conditions.

Analyses of transient events were performed with the recirculation pump (RPT) in service and out of service, with normal scram speed (NSS), technical specification scram speed (TSSS), and at exposures of end-of-cycle and at end-of-cycle -2000 MWD/MTU (4150 MWD/MTU) as shown in following table.

The loss of feedwater heating event was analyzed on a generic basis and the delta CPR results are bounding values.

Transient*	% Power/ % Flow	Maximum Heat Flux	Maximum Power	Maximum Pressure	Delta CPR GE Fuel	Delta CPR ANF Fuel
LRWB, NSS RPT Operable	104/106	115%	295%	1165 psig	0.25	0.23
LRWB, NSS RPT Inoperable	104/106	121%	390%	1175 psig	0.31	0.28
LRWB, TSSS RPT Operable	104/106	121%	370%	1170 psig	0.33	0.29
LRWB, TSSS RPT Inoperable	104/106	127%	440%	1183 psig	0.37	0.33
LRWB, TSSS RPT Inoperable end-of-cycle minus 2000 MWD/MTU	104/106	112%	304%	1167 psig	0.11	0.12
FWCF, NSS RPT Operable	47/106	54%	156%	1015 psig	0.26	0.24
FWCF, NSS RPT Inoperable	47/106	57%	205%	1020 psig	0.31	0.29
FWCF, TSSS RPT Operable	47/106	55%	172%	1020 psig	0.30	0.27
LOFH	N/A	N/A	N/A	N/A	0.09	0.09

5.2 Analyses For Reduced Flow Operation — Reference 9.3

Limiting Transient: Recirculation Flow Increase

5.4 ASME Overpressurization Analysis — Reference 9.3

Limiting Event: MSIV Closure

Worst Single Failure: MSIV Position Scram Trip

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*Normal scram speed (NSS) is based on measured plant scram insertion data, see Section 7.2.3.1.

Maximum Pressure	1313 psig
Maximum Steam Dome Pressure	1285 psig

5.5 Control Rod Withdrawal Error

Initial Control Rod Pattern for CRWE Analysis Figure 5.1

Rod Block Monitor Setting	Distance Withdrawn (ft)	ANF Delta-CPR	GE Delta-CPR
106%*	4.5	0.20	0.23
107%	4.5	0.20	0.23
108%	5.0	0.22	0.25

5.6 Fuel Loading Error

Delta CPR	0.13

5.7 Determination Of Thermal Margins

Summary of Thermal Margin Requirements

All system transient results at the more limiting increased flow conditions (106%). LRWB results for the more limiting power (design basis condition - 104%) for this transient.

FWCF results for the more limiting power (minimum allowable - 47%) condition for this transient.

*Rod Block Monitor Setting (RBM) of 106% for Cycle 3.

Event	Equipment Operational Status	Delta CPR GE Fuel	Delta CPR ANF Fuel	MCPR Limit GE Fuel	MCPR Limit ANF Fuel	Model	
LRWB	RPT Operable, NSS	0.25	0.23	1.31	1.29	COTRANSA/XCOBRA-T	
LRWB	RPT Inoperable, NSS	0.31	0.28	1.37	1.34	"	"
LRWB	RPT Operable, TSSS	0.33	0.29	1.39	1.35	"	"
LRWB	RPT Inoperable, TSSS	0.37	0.33	1.43	1.39	"	"
LRWB	RPT Inoperable, TSSS, EOC -2000 MWD/MTU	0.11	0.12	1.17	1.18	"	"
FWCF	RPT Operable, NSS	0.26	0.24	1.32	1.30	"	"
FWCF	RPT Inoperable, NSS	0.31	0.29	1.37	1.35	"	"
FWCF	RPT Operable, TSSS	0.30	0.27	1.36	1.34	"	"
LOFH	N/A	0.09	0.09	1.15	1.15	XTGBWR	

MCPR Operating Limits At Rated Condition For Cycle Exposures Less Than EOC -2000 MWD/MTU (100 To 106% Flow)

Fuel Type	MCPR Limit (107% RBS)
ANF	1.26
GE	1.29

MCPR Operating Limits At Rated Condition From EOC -2000 MWD/MTU To EOC (100 To 106% Flow)

Fuel Type	MCPR Limit
ANF	1.30
GE	1.32

MCPR Limits at Off-Rated Conditions

Figure 5.2

Reduced Flow MCPR Limit

Reference 9.3

6.0 POSTULATED ACCIDENTS

6.1 Loss-Of-Coolant Accident

6.1.1 Break Location Spectrum — Reference 9.4

6.1.2 Break Size Spectrum — Reference 9.4

6.1.3 MAPLHGR Analyses (ANF Fuel) — Reference 9.5

Limiting Break: Split Break in the Recirculation Suction Piping With an Area Equal to Sixty Percent of the Double-Ended Cross-Sectional Pipe Area

Bundle Average Exposure (MWD/MTM)	MAPLHGR (kw/ft)	Peak Clad Temperature, °F	Peak Local MWR, %
0	13.0	1765	0.49
5,000	13.0	1766	0.48
10,000	13.0	1765	0.47
15,000	13.0	1772	0.47
20,000	13.0	1788	0.54
25,000	11.3	1699	0.34
30,000	9.4	1521	0.17
35,000	7.9	1397	0.10

6.2 Control Rod Drop Accident — Reference 9.7

Dropped Control Rod Worth, mK	10.5
Doppler Coefficient dK/KdT, 1/°F	-9.5×10^{-6}
Effective Delayed Neutron Fraction	0.0050
Four-Bundle Local Peaking Factor	1.23
Maximum Deposited Fuel Rod Enthalpy (cal/gm)	170.

7.0 TECHNICAL SPECIFICATIONS

7.1 Limiting Safety System Settings

7.1.1 MCPR Fuel Cladding Integrity Safety Limit

MCPR Safety Limit 1.06

7.1.2 Steam Dome Pressure Safety Limit

Pressure Safety Limit 1346 psig

7.2 Limiting Conditions For Operation

7.2.1 Average Planar Linear Heat Generation Rate Limits For ANF 8x8 Fuel

Bundle Average Exposure (MWD/MTU)	MAPLHGR (Kw/ft)
0	13.0
5,000	13.0
10,000	13.0
15,000	13.0
20,000	13.0
25,000	11.3
30,000	9.4
35,000	7.9

7.2.2 Minimum Critical Power Ratio

Rated Condition MCPR Operating Limit Up To EOC -2000 MWD/MTU Exposure (100 To 106% Flow)

Fuel Type	Limit (107% RBS)
ANF	1.26
GE	1.29

Rated Conditions MCPR Operating Limits From EOC -2000 MWD/MTU To EOC (100% To 106% Flow)

Fuel Type	Limit
ANF	1.30
GE	1.32

Reduced Flow MCPR Limit (all cycle exposures) Figure 5.2

7.2.3 Surveillance Requirements

7.2.3.1 Scram Insertion Time Surveillance

The ANF reload safety analyses were performed using the control rod insertion times shown below which are based on plant data. In the event that plant surveillance shows these scram insertion times may be exceeded, the plant thermal margin limits are to default to the values which correspond to the technical specification (TSSS) control rod scram times.

Position Inserted From Fully Withdrawn	Average Rod Time In Seconds As Defined In Footnote*
Notch 45	0.404
Notch 39	0.660
Notch 25	1.504
Notch 5	2.624

The limiting transient using technical specification control rod scram times is the generator load rejection without bypass. The respective MCPR values for ANF and GE fuel during Cycle 3 are 1.35 and 1.39 using the technical specification control rod speeds with the recirculation pump trip operable.

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*Slowest measured average control rod insertion time to specified notches for each group of four control rods arranged in a 2x2 array.

7.2.3.2 Stability Surveillance

Acceptable surveillance procedures for potentially unstable operation shall be instituted in the portion of the operating power-flow map bounded by the 80% flow control line and 45% of rated recirculation flow.

7.2.3.3 Technical Specification LHGR Surveillance

The Technical Specification linear heat generation rate (LHGR) limit versus average planar exposure for ANF 8x8 reload fuel is shown in Figure 7.1. This figure was developed from information contained in Reference 9.1, and the region of permissible operation is shown.

TABLE 4.1 NEUTRONIC DESIGN VALUES

Fuel Pellet	
Fuel Material	UO_2 Sintered Pellets
Density, g/cc	10.36
% of T.D.	94.5
Diameter	
Enriched Fuel	0.4055
Natural Fuel	0.4045
Fuel Rod	
Fuel Length, inches	150
Cladding Material	Zircaloy-2
Clad, I.D., inches	0.414
Clad, O.D., inches	0.484
Fuel Assembly	
Number of Fuel Rods	62
Number of Inert Water Rods	2
Fuel Rod Enrichments	Figure 4.1
Fuel Rod Pitch, inches	0.641
Fuel Assembly Loading, KgU	176.0

TABLE 4.1 NEUTRONIC DESIGN VALUES
(Continued)

Core Data	
Number of Fuel Assemblies	764
Rated Thermal Power, MW	3323
Rated Core Flow, Mlbm/hr	108.5
Core Inlet Subcooling, BTU/lbm	19.0
Reactor Pressure, psia	1008.0
Channel Thickness, inch	0.100
Fuel Assembly Pitch, inch	6.00
Water Gap Thickness (symmetric), inch	0.522
Control Rod Data	
Absorber Material	B_4C
Total Blade Span, inch	9.75
Total Blade Support Span, inch	1.58
Blade Thickness, inch	0.260
Blade Face-To-Face Internal Dimension, inch	0.200
Absorber Rods Per Blade	76
Absorber Rod Outside Diameter, inch	0.188
Absorber Rod Inside Diameter, inch	0.138
Absorber Density, % of Theoretical	70.0

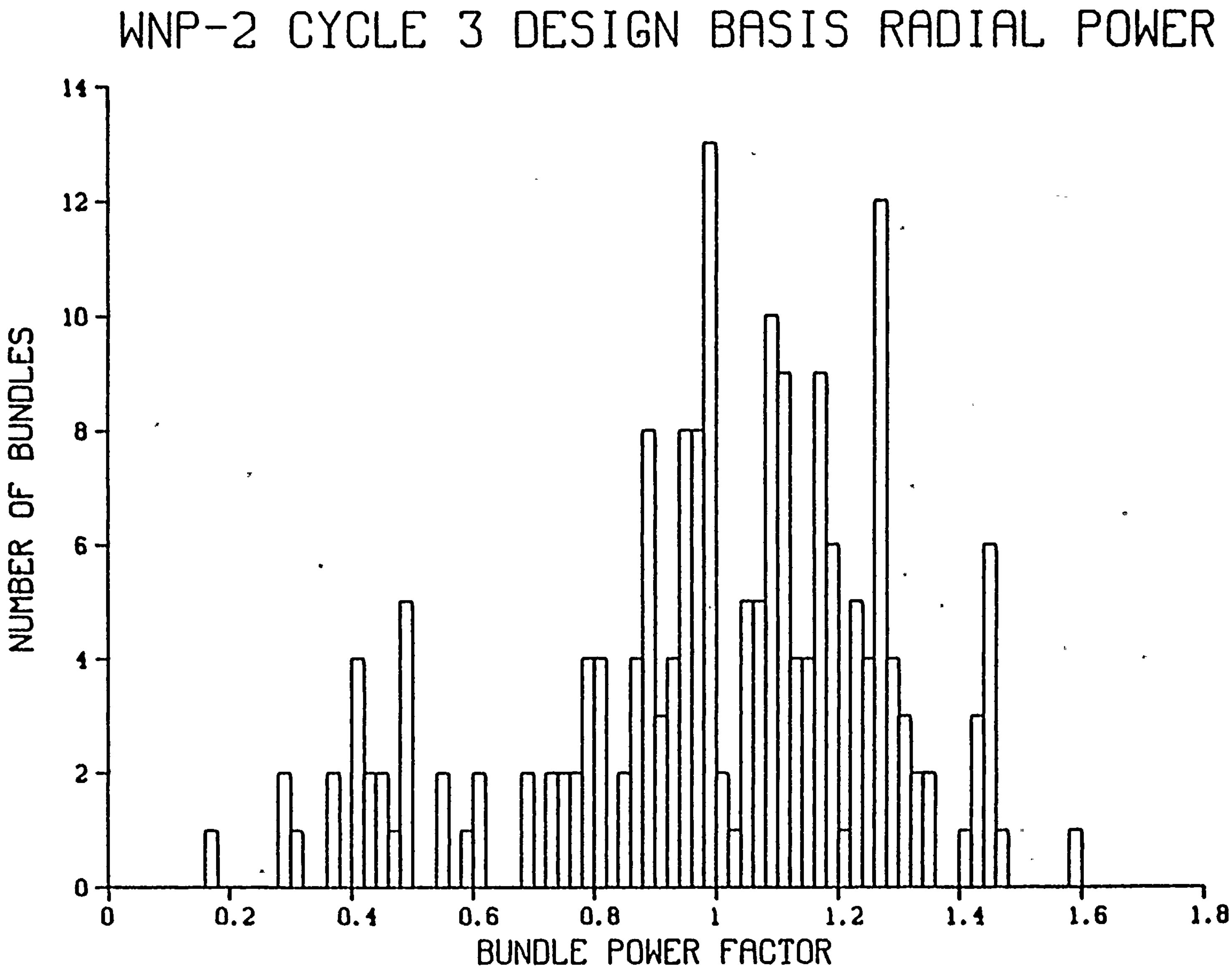

Figure 3.1 Radial Power Histogram For 1/4 Core Safety Limit Model

LL 0.91	L 0.95	ML 1.01	M 1.05	M 1.05	ML 1.01	L 0.95	LL 0.91
L 0.95	ML 0.97	H 1.07	ML* 0.89	H 1.04	H 1.07	M 1.03	L 0.95
ML 1.01	H 1.07	H 1.02	H 1.01	H 0.99	H 1.01	ML* 0.91	ML 1.01
M 1.05	ML* 0.89	H 1.01	W 0.00	M 0.91	H 0.99	H 1.04	M 1.05
M 1.05	H 1.04	H 0.99	M 0.91	W 0.00	H 1.00	M 0.95	M 1.04
ML 1.01	H 1.07	H 1.01	H 0.99	H 1.00	H 1.01	H 1.07	M 1.07
L 0.95	M 1.03	ML* 0.91	H 1.04	M 0.95	H 1.07	ML* 0.97	ML 1.05
LL 0.91	L 0.95	ML 1.01	M 1.05	M 1.04	M 1.07	ML 1.05	L 1.01

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Figure 3.2 WNP-2 Cycle 3 Safety Limit Local Peaking Factors (ANF Fuel)

LL	L	ML	M	M	ML	L	LL
L	ML	H	ML*	H	H	M	L
ML	H	H	H	H	H	ML*	ML
M	ML*	H	W	M	H	H	M
M	H	H	M	W	H	M	M
ML	H	H	H	H	H	H	M
L	M	ML*	H	M	H	ML*	ML
LL	L	ML	M	M	M	ML	L

LL	RODS (3)	---	1.50 W/O U235
L	RODS (7)	---	2.00 W/O U235
ML	RODS (9)	---	2.57 W/O U235
M	RODS (16)	---	2.94 W/O U235
H	RODS (22)	---	3.54 W/O U235
ML*	RODS (5)	---	2.57 W/O U235 + 2.00 W/O GD203
W	RODS (2)	---	INERT WATER ROD

Figure 4.1 WNP-2 Cycle 3 Enriched Zone Enrichment Distribution

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	B	B	B	B	D	B	B	B	D	B	B	B	D	C	A
2	B	D	B	B	B	D	B	B	B	D	B	D	B	D	B
3	B	B	C	B	C	B	C	B	C	B	C	B	C	B	B
4	B	B	B	D	B	B	B	D	B	B	B	D	B	D	A
5	D	B	C	B	C	B	C	B	C	B	C	B	C	B	B
6	B	D	B	B	B	D	B	B	B	D	B	D	B	D	A
7	B	B	C	B	C	B	C	B	C	B	C	B	C	B	A
8	B	B	B	D	B	B	B	D	B	D	B	D	B	A	
9	D	B	C	B	C	B	C	B	C	B	D	C	A		
10	B	D	B	B	B	D	B	D	B	D	B	B	A		
11	B	B	C	B	C	B	C	B	D	B	B				
12	B	D	B	D	B	D	B	D	C	B					
13	D	B	C	B	C	B	C	B	A	A					
14	C	D	B	D	B	D	B	A							
15	A	B	B	A	B	A	A								

Fuel Type	Number of Assemblies	Description
A	56	GE 8x8 Type II 1.76 w/o U-235 (Cycle 1)
B	432	GE 8x8 Type III 2.19 w/o U-235 (Cycle 1)
C	128	ANF 8x8 2.72 w/o U-235 (Cycle 2)
D	148	ANF 8x8 2.72 w/o U-235 (Cycle 3)

Figure 4.2 WNP-2 Cycle 3 Reference Loading Pattern By Fuel Type (One Quarter Of Symmetrical Core Loading)

	2	6	10	14	18	22	26	30	34	38	42	46	50	54	58	
59					--	--	--	--	--	--	--					59
55				--	--	00	--	36	--	00	--	--				55
51			--	--	--	--	--	--	--	--	--	--	--			51
47		--	--	20	--	14	--	00	--	14	--	20	--	--		47
43	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	43
39	--	00	--	14	--	00	--	20	--	00	--	14	--	00	--	39
35	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	35
31	--	36	--	00	--	20	--	12	--	20	--	00	--	36	--	31
27	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	27
23	--	00	--	14	--	00	--	20	--	00*	--	14	--	00	--	23
19	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	19
15		--	--	20	--	14	--	00	--	14	--	20	--	--		15
11			--	--	--	--	--	--	--	--	--	--	--			11
7				--	--	00	--	36	--	00	--	--				7
3					--	--	--	--	--	--	--					3
	2	6	10	14	18	22	26	30	34	38	42	46	50	54	58	

* Control Rod Being Withdrawn
Rod Position in Notches Withdrawn
Full in = 00
Full out = --

Figure 5.1 WNP-2 Cycle 3 Control Rod Withdrawal Analysis Initial Control Rod Pattern

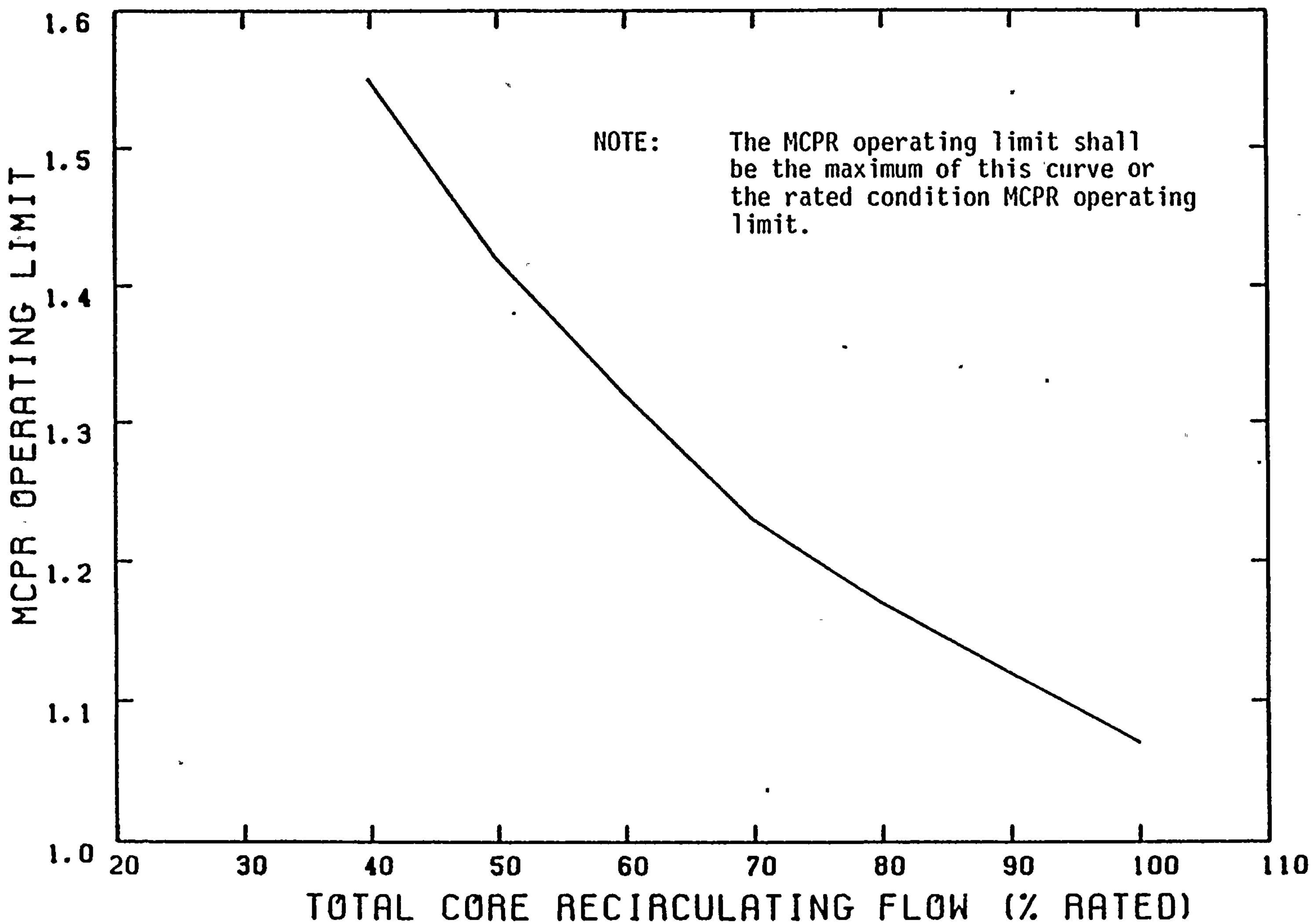
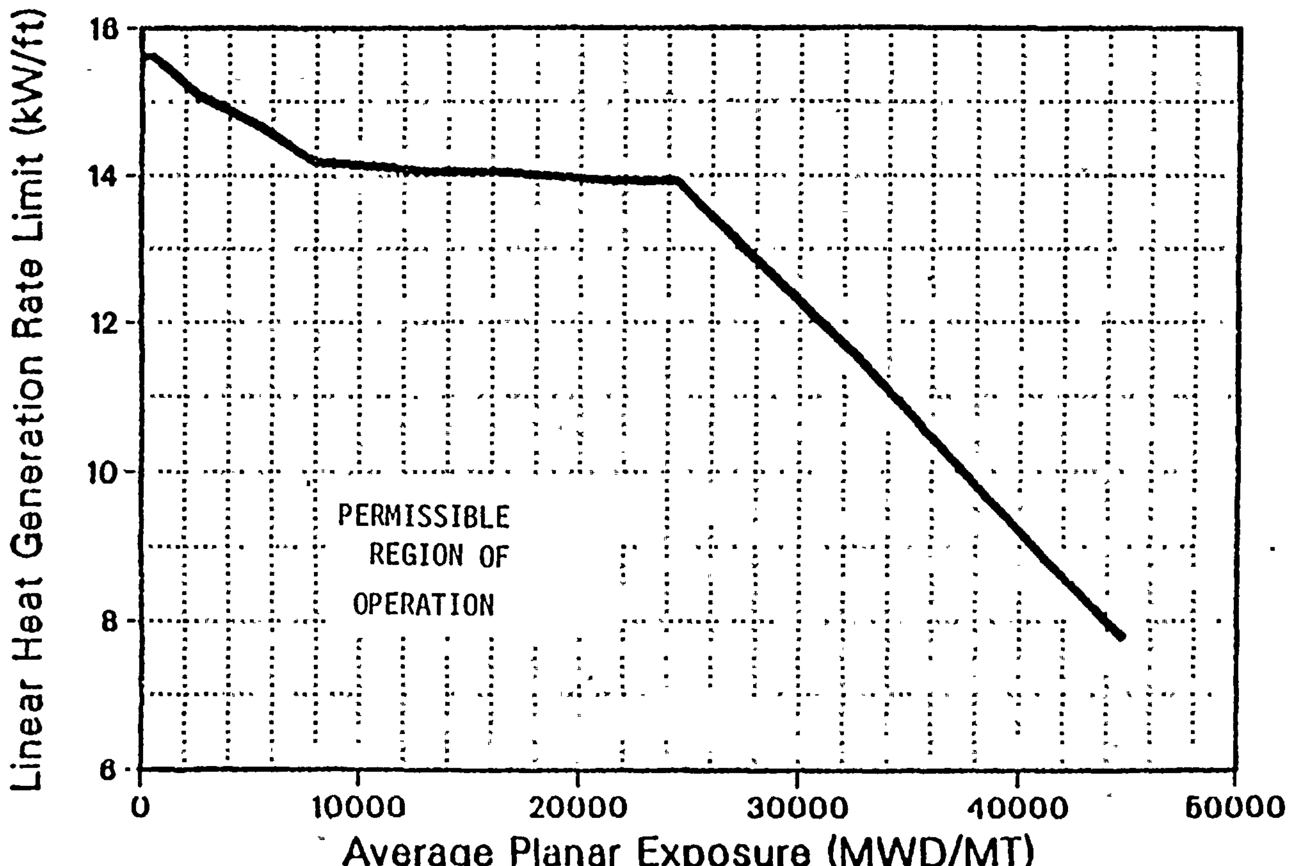


Figure 5.2 Reduced Flow MCPR Operating Limit



EXP	LHGR
0	15.62
610	15.62
2,580	15.10
5,230	14.71
7,940	14.19
10,470	14.13
13,220	14.06
15,990	14.06
18,780	14.00
21,590	13.93
24,420	13.93
27,280	13.08
30,150	12.24
33,050	11.40
35,960	10.47
38,900	9.56
41,830	8.65
44,760	7.77

Figure 7.1 Linear Heat Generation Rate (LHGR) Limit Versus Average Planar Exposure ANF 8x8 Fuel

9.0 ADDITIONAL REFERENCES

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APPENDIX A

SINGLE LOOP OPERATION (SLO)

The NSSS supplier, General Electric (GE), has provided analyses which demonstrate the safety of plant operation with a single recirculation loop out of service for an extended period of time. These analyses restrict the overall operation of the plant to lower bundle power levels and lower nodal power levels than are allowed when both recirculation systems are in operation. The physical interdependence between core power and recirculation flow rate inherently limits the core to less than rated power. Because the ANF fuel was designed to be compatible with the coresident fuel in thermal hydraulic, nuclear, and mechanical design performance, and because the ANF methodology has given results which are consistent with those of the previous analyses for normal two-loop operation, the analyses performed by GE for single loop operation are also applicable to single loop operation with fuel and analyses provided by ANF.

With a single recirculation loop in operation, the GE analyses supported continued operation with an increase of 0.01 in the MCPR safety limit. Because of the similarity between the ANF and GE fuel types making up the core, and because of the similarity in the magnitude of the uncertainties which determine the MCPR safety limit, this small increase in the safety limit value is also appropriate for operation with ANF fuel and analyses. For Cycle 3 operation with both recirculation loops in operation, the MCPR safety limit is 1.06, which is the same value as was used for the previous cycle. For Cycle 3 operation with a single recirculation loop in service, the MCPR safety limit is 1.07, which is also the same value as was used for the previous cycle.

The consequences of core-wide transients at the reduced power and flow conditions necessitated by single loop operation are bounded by the consequences of these events at rated conditions. The additional conservatism imposed by the reduced flow MCPR operating limits specified in the main body of this report assures that the MCPR safety limit will not be violated during anticipated operational occurrences with a single recirculation loop in service. No modification to the delta-CPR defining the rated conditions MCPR operating limit is required, and the reduced flow MCPR limit curve remains conservatively applicable during single loop operation. Because the reduced flow MCPR limit curves are based on equipment performance which physically cannot happen during single loop operation, the added conservatism present in the curves compensates for the penalties associated with increased uncertainties in the MCPR safety limit and control rod drive performance. The reduced flow MCPR limit curves are applicable without modification during single loop operation.

To support operation of WNP-2 with a core composed of GE P8x8R and ANF 8x8 fuel with a single recirculation pump operating, ANF recommends the conservative use of GE fuel MAPLHGR limits for the similar GE P8x8R fuel design with a multiplier of 0.84 applied for single loop operation. The basis for this recommendation is as follows:

- The phenomena which require the reduction in MAPLHGR limits are a result of operation of the WNP-2 system with a single active recirculation loop, and are equally applicable to both GE and ANF fuel designs; and

- The analytical methods used by GE have yielded conservative MAPLHGR limits relative to the MAPLHGR limits obtained using the approved ANF analytical methods.

Therefore, applying the more conservative GE MAPLHGR limits to ANF fuel provides a limit which assures conformance with the criteria of 10 CFR 50.46.

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WNP-2 CYCLE 3 RELOAD ANALYSIS

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