Browns Ferry Nuclear Plant
Unit 3, Cycle 9

CORE OPERATING LIMITS REPORT (COLR)

TENNESSEE VALLEY AUTHORITY
Nuclear Fuel Division
BWR Fuel Engineering Department

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1. INTRODUCTION

This Core Operating Limits Report for Browns Ferry Unit 3, Cycle 9 is prepared in accordance with the requirements of Browns Ferry Technical Specification 5.6.5. The core operating limits presented here were developed using NRC-approved methods (References 1 and 2). Results from the reload analyses for Browns Ferry Unit 3, Cycle 9 are documented in Reference 3.

The following core operating limits are included in this report:

a. Average Planar Linear Heat Generation Rate (APLHGR) Limit
(Technical Specifications 3.2.1 and 3.7.5)

b. Linear Heat Generation Rate (LHGR) Limit
(Technical Specification 3.2.3)

c. Minimum Critical Power Ratio Operating Limit (OLMCPR)
(Technical Specifications 3.2.2, 3.3.4.1, and 3.7.5)

d. Average Power Range Monitor (APRM) Flow Biased Rod Block Trip Setting
(Technical Requirements Manual Section 5.3.1 and Table 3.3.4-1)

e. Rod Block Monitor (RBM) Trip Setpoints and Operability
(Technical Specification Table 3.3.2.1-1)

f. Shutdown Margin (SDM) Limit
(Technical Specification 3.1.1)

2. APLHGR LIMIT (TECHNICAL SPECIFICATIONS 3.2.1 AND 3.7.5)

The APLHGR limits for full power and flow conditions for each type of fuel as a function of exposure are shown in Figures 1-6. The APLHGR limits for the GE7B, GE11 and GE13 assemblies are for the most limiting lattice (excluding natural uranium) at each exposure point. The specific values for each lattice are given in Reference 4.

These APLHGR limits are adjusted for off-rated power and flow conditions using the ARTS factors, MAPFAC(P) and MAPFAC(F). The reduced power factor, MAPFAC(P), is given in Figure 7. Similarly, adjustments for reduced flow operation are performed using the MAPFAC(F) corrections given in Figure 8. Both factors are multipliers used to reduce the standard APLHGR limit. The most limiting power-adjusted or flow-adjusted value is taken as the APLHGR operating limit for the off-rated condition.

The APLHGR limits in figures 1-6 are applicable for both Turbine Bypass In-Service and Out-Of-Service. The off-rated power and flow corrections in figures 7 and 8 bound both Turbine Bypass In-Service and Out-Of-Service operation. No corrections are required to the APLHGR limits for TBOOS for either rated or off-rated operation.

3. LHGR LIMIT (TECHNICAL SPECIFICATION 3.2.3)

The LHGR limit for unit 3 cycle 9 is fuel type dependent , as shown below:

Fuel Type	LHGR Limit
GE7B (BP8X8R)	13.4 kw/ft
GE11	14.4 kw/ft
GE13	14.4 kw/ft

4. OLMCPR (TECHNICAL SPECIFICATIONS 3.2.2, 3.3.4.1, AND 3.7.5)

a. The MCPR Operating Limit for rated power and flow conditions, OLMCPR(100), is equal to the fuel type and exposure dependent limit shown in Figure 9. For cycle 9, only GE13 results are supplied since they bound all bundle types. The actual OLMCPR(100) value is dependent upon the scram time testing results, as described below:

$$\tau = 0.0 \quad \text{or} \quad \frac{\tau_{ave} - \tau_B}{\tau_A - \tau_B}, \quad \text{whichever is greater}$$

where; τ_A = **1.096** sec (analytical Option A scram time limit - based on dropout time for notch position 36)

$$\tau_{ave} = \frac{\sum_{i=1}^{n} \tau_i}{n}$$

$$\tau_B = \mu + 1.65 * \sigma * \left[\frac{N}{n}\right]^{\frac{1}{2}}$$

where; μ = **0.830** sec (mean scram time used in transient analysis - based on dropout time for notch position 36)

σ = **0.019** sec (standard deviation of μ)

N = Total number of active rods measured in Technical Specification Surveillance Requirement SR3.1.4.1

n = Number of surveillance rod tests performed to date in cycle

τ_i = Scram time (dropout time) from fully withdrawn to notch position 36 for the i^{th} rod

b. Option A OLMCPR limits (τ=1.0) shall be used prior to the determination of τ in accordance with SR 3.1.4.1.

c. For off-rated power and flow conditions, power-adjusted and flow-adjusted operating limits are determined from Figures 10 and 11, respectively. The most limiting power-dependent or flow-dependent value is taken as the OLMCPR for the off-rated condition.

d. OLMCPR limits and off-rated corrections are provided for Recirculation Pump Trip out-of-service (RPTOOS) or Turbine Bypass out-of-service (TBOOS) conditions. These events are analyzed separately and the core is not analyzed for both systems Out-Of-Service at the same time.

5. APRM FLOW BIASED ROD BLOCK TRIP SETTING (TECHNICAL REQUIREMENTS MANUAL SECTION 5.3.1 AND TABLE 3.3.4-1)

The APRM Rod Block trip setting shall be:

$S_{RB} \leq (0.66W + 61\%)$ Allowable Value

$S_{RB} \leq (0.66W + 59\%)$ Nominal Trip Setpoint (NTSP)

where:

S_{RB} = Rod Block setting in percent of rated thermal power (3458 MWt)

W = Loop recirculation flow rate in percent of rated

The APRM Rod Block trip setting is clamped at a maximum allowable value of 115% (corresponding to a NTSP of 113%).

6. ROD BLOCK MONITOR (RBM) TRIP SETPOINTS AND OPERABILITY (TECHNICAL SPECIFICATION TABLE 3.3.2.1-1)

The RBM trip setpoints and applicable power ranges shall be as follows:

RBM Trip Setpoint	Allowable Value (AV)	Nominal Trip Setpoint (NTSP)	
LPSP	27%	25%	
IPSP	62%	60%	
HPSP	82%	80%	
LTSP - unfiltered - filtered	118.7% 117.7%	117.0% 116.0%	(1),(2)
ITSP - unfiltered - filtered	113.7% 112.9%	112.0% 111.2%	(1),(2)
HTSP - unfiltered - filtered	108.7% 107.9%	107.0% 106.2%	(1),(2)
DTSP	90%	92%	

Notes: (1) These setpoints are based upon a MCPR operating limit of 1.29 using a safety limit of 1.10. This is consistent with a MCPR operating limit of 1.25 using a safety limit of 1.07, as reported in references 6, 7, and 8.

(2) The unfiltered setpoints are consistent with a nominal RBM filter setting of 0.0 seconds (reference 8). The filtered setpoints are consistent with a nominal RBM filter setting $\leq$ 0.5 seconds (reference 7).

The RBM setpoints in Technical Specification Table 3.3.2.1-1 are applicable when:

THERMAL POWER	Applicable MCPR	Notes from Table 3.3.2.1-1
$\geq$ 27% and < 90% RATED	< 1.75	(a), (b), (f), (h)
$\geq$ 90% RATED	< 1.44	(g)

Note: The given MCPR operating limits are adjusted to correspond to a MCPR safety limit of 1.10. The values shown correspond to operating limits of 1.70 and 1.40 given the original 1.07 MCPR safety limit used in reference 6.

7. SHUTDOWN MARGIN (SDM) LIMIT (TECHNICAL SPECIFICATION 3.1.1)

The core shall be subcritical with the following margin with the strongest OPERABLE control rod fully withdrawn and all other OPERABLE control rods fully inserted.

$$SDM \geq 0.38\% \text{ dk/k}$$

8. REFERENCES

1. NEDE-24011-P-A-13, "General Electric Standard Application for Reactor Fuel", August 1996.

2. NEDE-24011-P-A-13-US, "General Electric Standard Application for Reactor Fuel (Supplement for United States)", August 1996.

3. J11-03329SRLR Rev. 0, "Supplemental Reload Licensing Report for Browns Ferry Nuclear Plant Unit 3 Reload 8 Cycle 9", July 1998.

4. J11-03329MAPL Rev. 0, "Lattice-Dependent MAPLHGR Report for Browns Ferry Nuclear Plant Unit 3 Reload 8 Cycle 9", July 1998.

5. NEDC-32774P Rev. 1, "Safety Analyses for Browns Ferry Nuclear Plant Units 1, 2, and 3 Turbine Bypass and End-of-Cycle Recirculation Pump Trip Out-Of-Service", dated September 1997.

6. NEDC-32433P, "Maximum Extended Load Line Limit and ARTS Improvement Program Analyses for Browns Ferry Nuclear Plant Unit 1, 2, and 3", dated April 1995.

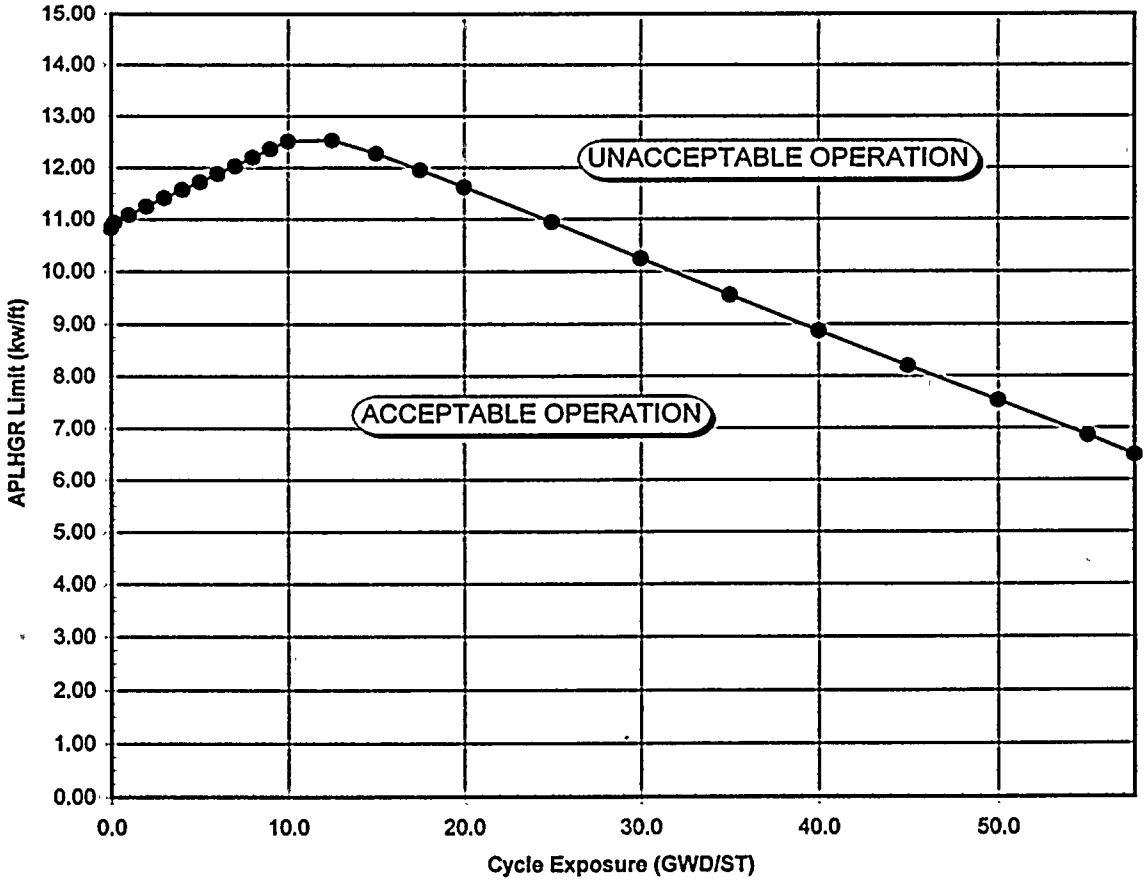
7. EDE-28-0990 Rev. 3 Supplement E, "PRNM (APRM, RBM, and RFM) Setpoint Calculations [ARTS/MELLL (NUMAC) - Power-Uprate Condition] for Tennessee Valley Authority Browns Ferry Nuclear Plant", dated October 1997.

8. EDE-28-0990 Rev. 2 Supplement E, "PRNM (APRM, RBM, and RFM) Setpoint Calculations [ARTS/MELLL (NUMAC) - Power-Uprate Condition] for Tennessee Valley Authority Browns Ferry Nuclear Plant", dated October 1997.

9. GE Letter LB#: 262-97-133, "Browns Ferry Nuclear Plant Rod Block Monitor Setpoint Clarification - GE Proprietary Information", dated September 12, 1997. [L32 970912 800]

10. GE Letter JAB-T8019a, "Technical Specification Changes for Implementation of Advanced Methods", dated June 4, 1998. [L32 980608 800]

Figure 1
APLHGR Limits for Bundle Type GE13-P9HTB386-12GZ
(GE13)

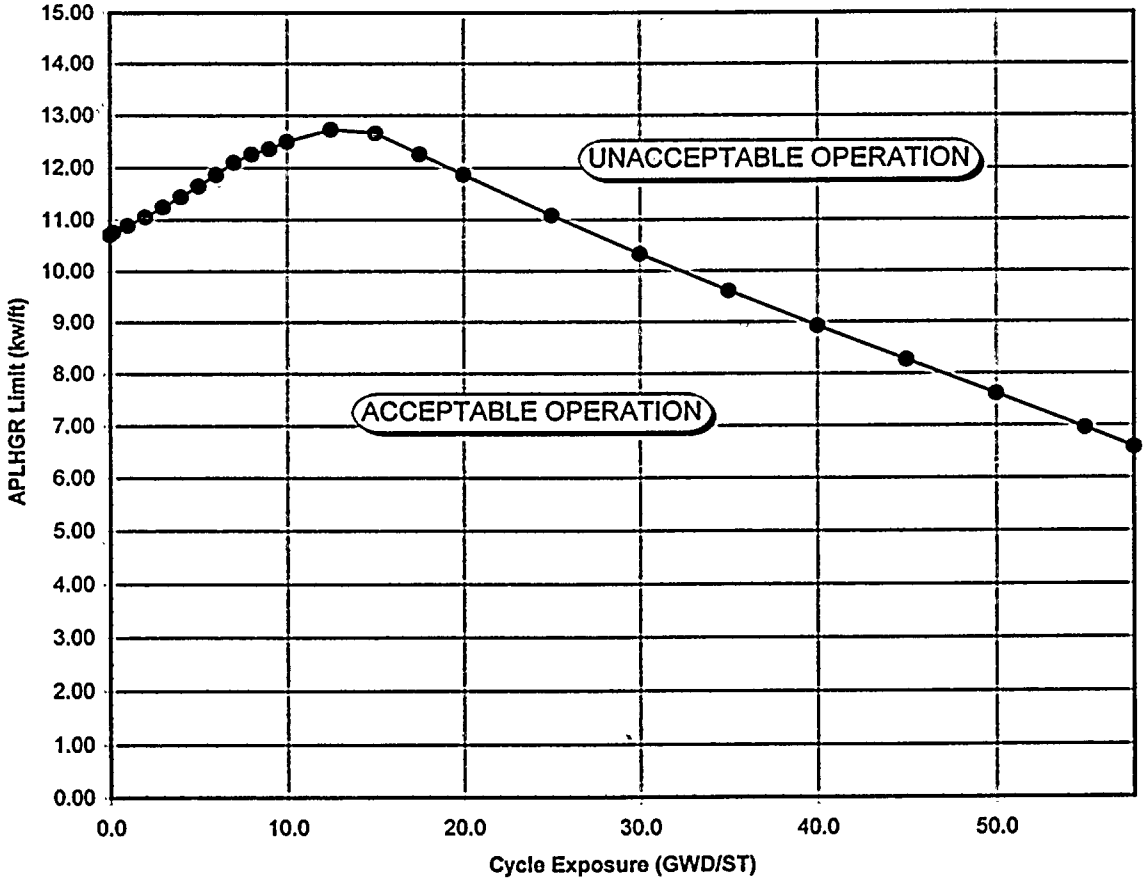


Most Limiting Lattice
for Each Exposure Point

Average Planar Exposure (GWD/ST)	LHGR Limit (kw/ft)	Average Planar Exposure (GWD/ST)	LHGR Limit (kw/ft)	Average Planar Exposure (GWD/ST)	LHGR Limit (kw/ft)
0.0	10.83	7.0	12.03	25.0	10.94
0.2	10.94	8.0	12.19	30.0	10.24
1.0	11.08	9.0	12.36	35.0	9.55
2.0	11.25	10.0	12.51	40.0	8.87
3.0	11.41	12.5	12.53	45.0	8.20
4.0	11.57	15.0	12.27	50.0	7.53
5.0	11.72	17.5	11.95	55.0	6.85
6.0	11.88	20.0	11.62	57.62	6.48

These values apply to both Turbine Bypass In-Service and Out-Of-Service.

Figure 2
APLHGR Limits for Bundle Type GE13-P9HTB372-11GZ
(GE13)

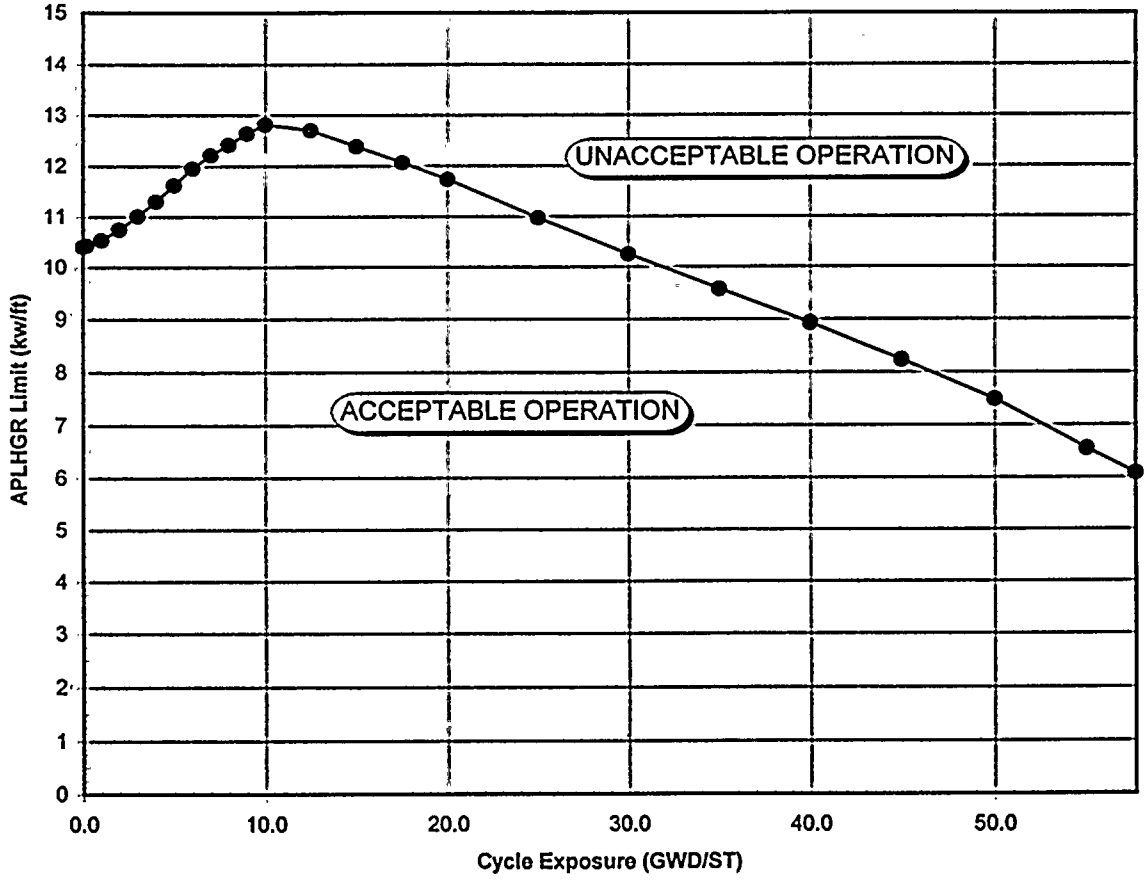


Most Limiting Lattice
for Each Exposure Point

Average Planar Exposure (GWD/ST)	LHGR Limit (kw/ft)	Average Planar Exposure (GWD/ST)	LHGR Limit (kw/ft)	Average Planar Exposure (GWD/ST)	LHGR Limit (kw/ft)
0.0	10.71	7.0	12.10	25.0	11.08
0.2	10.77	8.0	12.26	30.0	10.33
1.0	10.89	9.0	12.36	35.0	9.61
2.0	11.06	10.0	12.50	40.0	8.92
3.0	11.25	12.5	12.73	45.0	8.26
4.0	11.44	15.0	12.66	50.0	7.61
5.0	11.65	17.5	12.26	55.0	6.95
6.0	11.87	20.0	11.87	57.79	6.58

These values apply to both Turbine Bypass In-Service and Out-Of-Service.

Figure 3
APLHGR Limits for Bundle Type GE11-P9HUB323-5G5.0/4G4.0
(GE11)

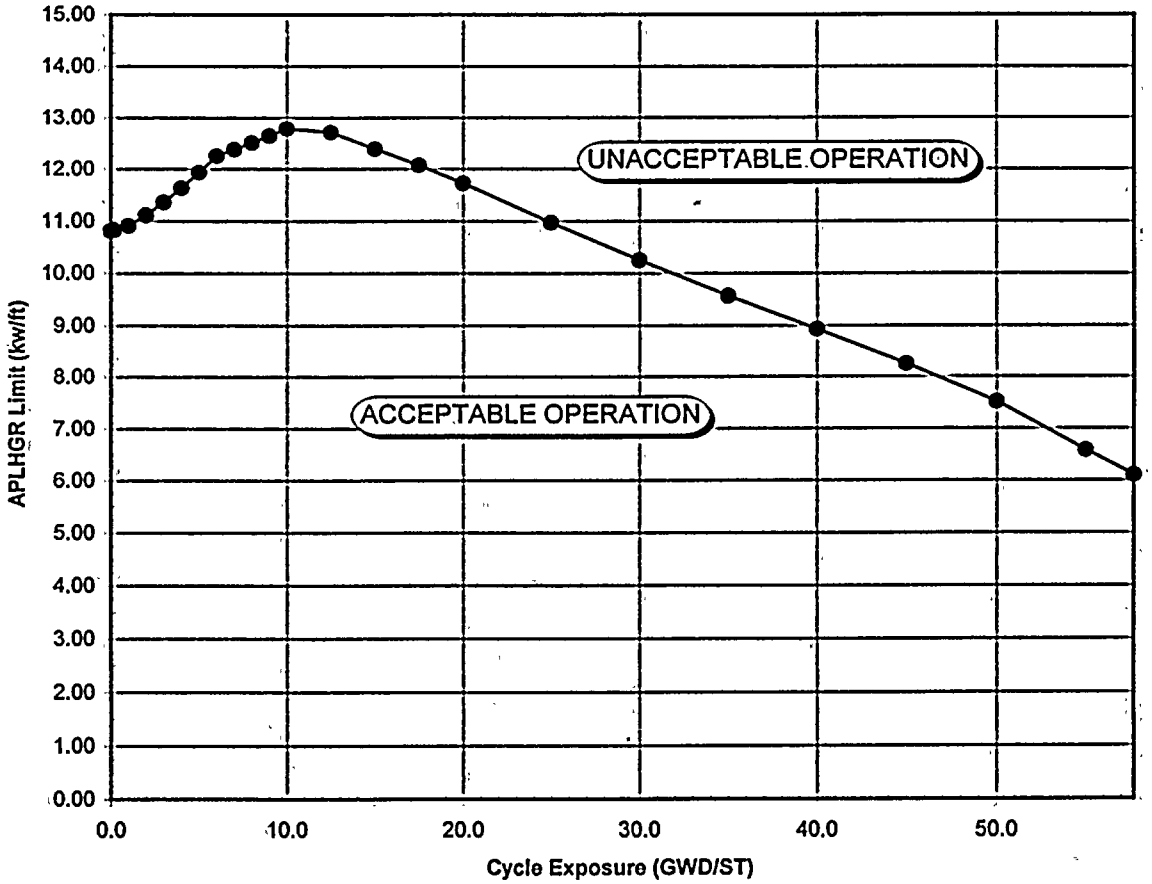


Most Limiting Lattice
for Each Exposure Point

Average Planar Exposure (GWD/ST)	LHGR Limit (kw/ft)	Average Planar Exposure (GWD/ST)	LHGR Limit (kw/ft)	Average Planar Exposure (GWD/ST)	LHGR Limit (kw/ft)
0.0	10.41	7.0	12.21	25.0	10.97
0.2	10.44	8.0	12.42	30.0	10.25
1.0	10.54	9.0	12.64	35.0	9.57
2.0	10.75	10.0	12.82	40.0	8.93
3.0	11.01	12.5	12.70	45.0	8.24
4.0	11.30	15.0	12.38	50.0	7.49
5.0	11.62	17.5	12.06	55.0	6.55
6.0	11.95	20.0	11.73	57.70	6.08

These values apply to both Turbine Bypass In-Service and Out-Of-Service.

Figure 4
APLHGR Limits for Bundle Type GE11-P9HUB323-8G4.0
(GE11)

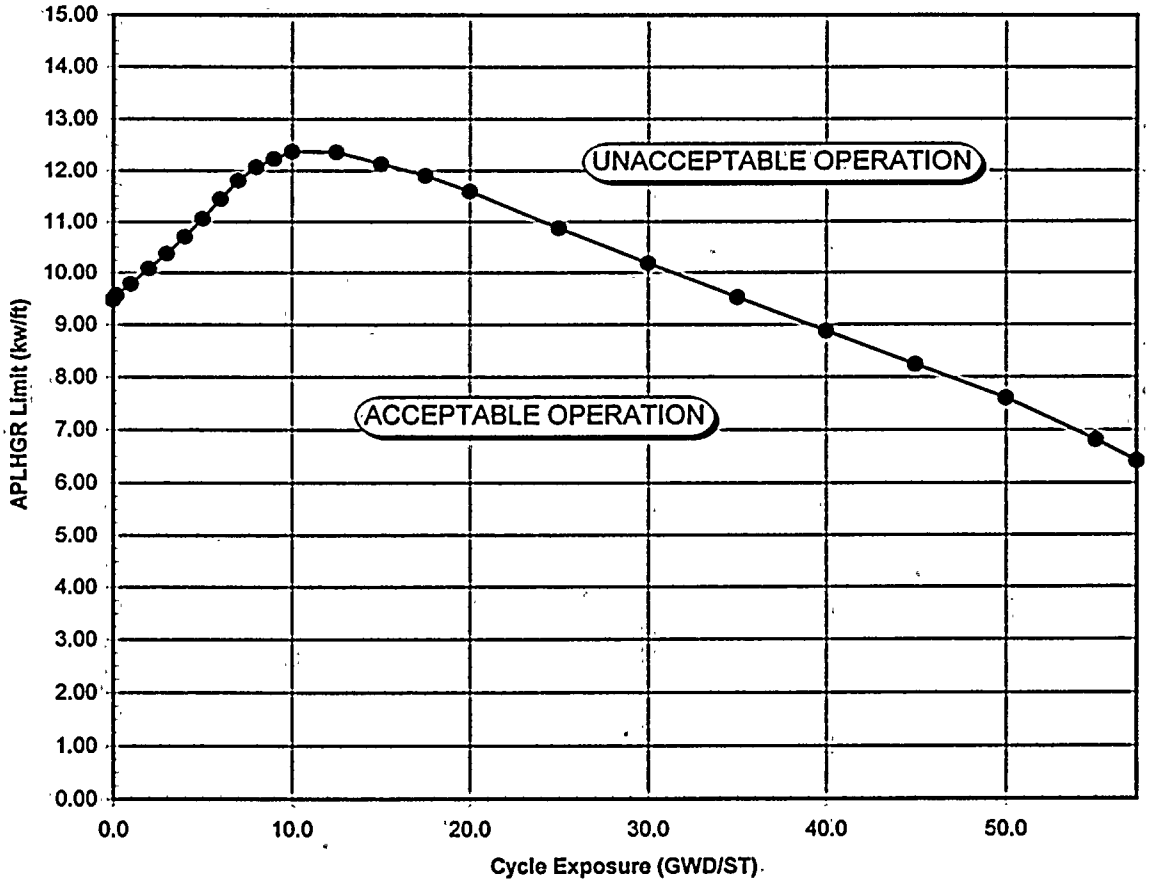


Most Limiting Lattice
for Each Exposure Point

Average Planar Exposure (GWD/ST)	LHGR Limit (kw/ft)	Average Planar Exposure (GWD/ST)	LHGR Limit (kw/ft)	Average Planar Exposure (GWD/ST)	LHGR Limit (kw/ft)
0.0	10.81	7.0	12.38	25.0	10.97
0.2	10.83	8.0	12.51	30.0	10.25
1.0	10.91	9.0	12.65	35.0	9.57
2.0	11.11	10.0	12.79	40.0	8.93
3.0	11.36	12.5	12.71	45.0	8.25
4.0	11.63	15.0	12.39	50.0	7.51
5.0	11.93	17.5	12.07	55.0	6.58
6.0	12.25	20.0	11.72	57.72	6.10

These values apply to both Turbine Bypass In-Service and Out-Of-Service.

Figure 5
APLHGR Limits for Bundle Type GE11-P9HUB325-14GZ
(GE11)

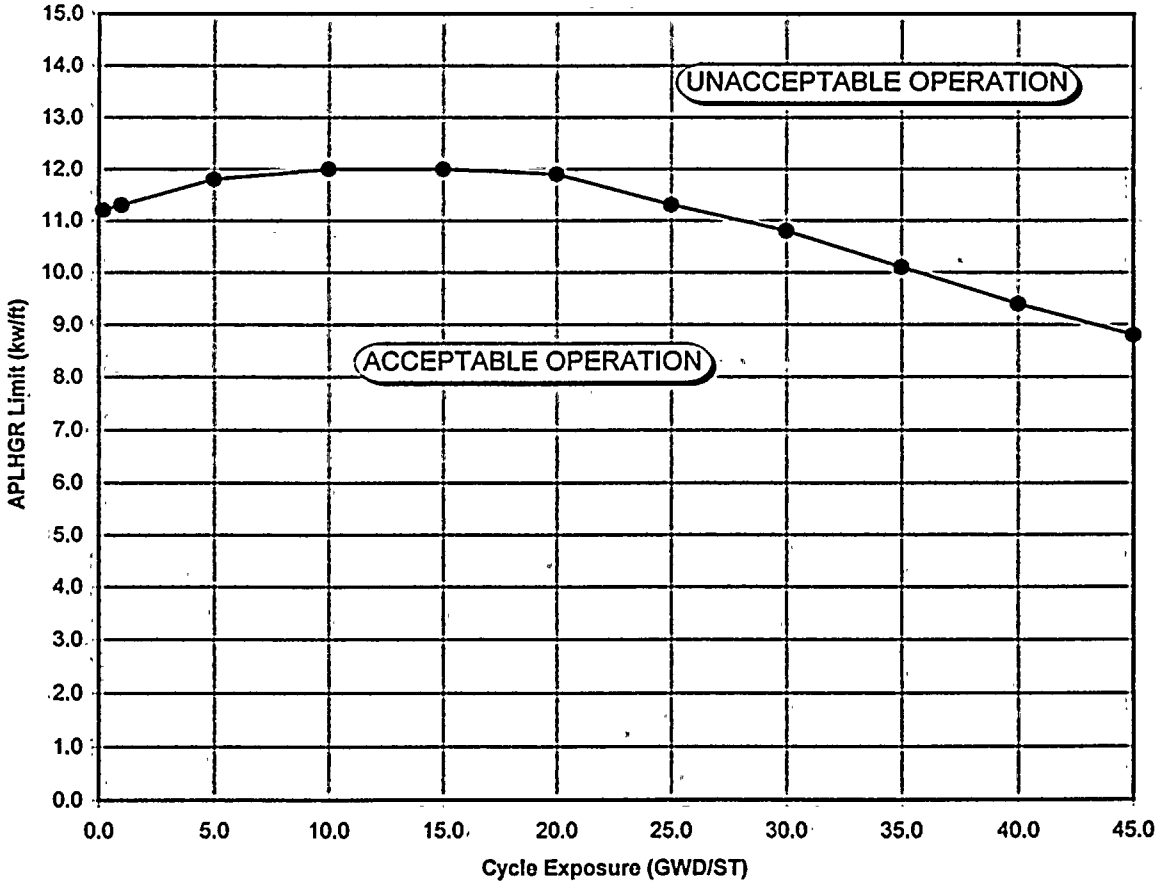


Most Limiting Lattice
for Each Exposure Point

Average Planar Exposure (GWD/ST)	LHGR Limit (kw/ft)	Average Planar Exposure (GWD/ST)	LHGR Limit (kw/ft)	Average Planar Exposure (GWD/ST)	LHGR Limit (kw/ft)
0.0	9.48	7.0	11.80	25.0	10.87
0.2	9.57	8.0	12.07	30.0	10.18
1.0	9.79	9.0	12.23	35.0	9.52
2.0	10.08	10.0	12.37	40.0	8.88
3.0	10.38	12.5	12.36	45.0	8.24
4.0	10.71	15.0	12.13	50.0	7.60
5.0	11.06	17.5	11.90	55.0	6.81
6.0	11.44	20.0	11.59	57.27	6.41

These values apply to both Turbine Bypass In-Service and Out-Of-Service.

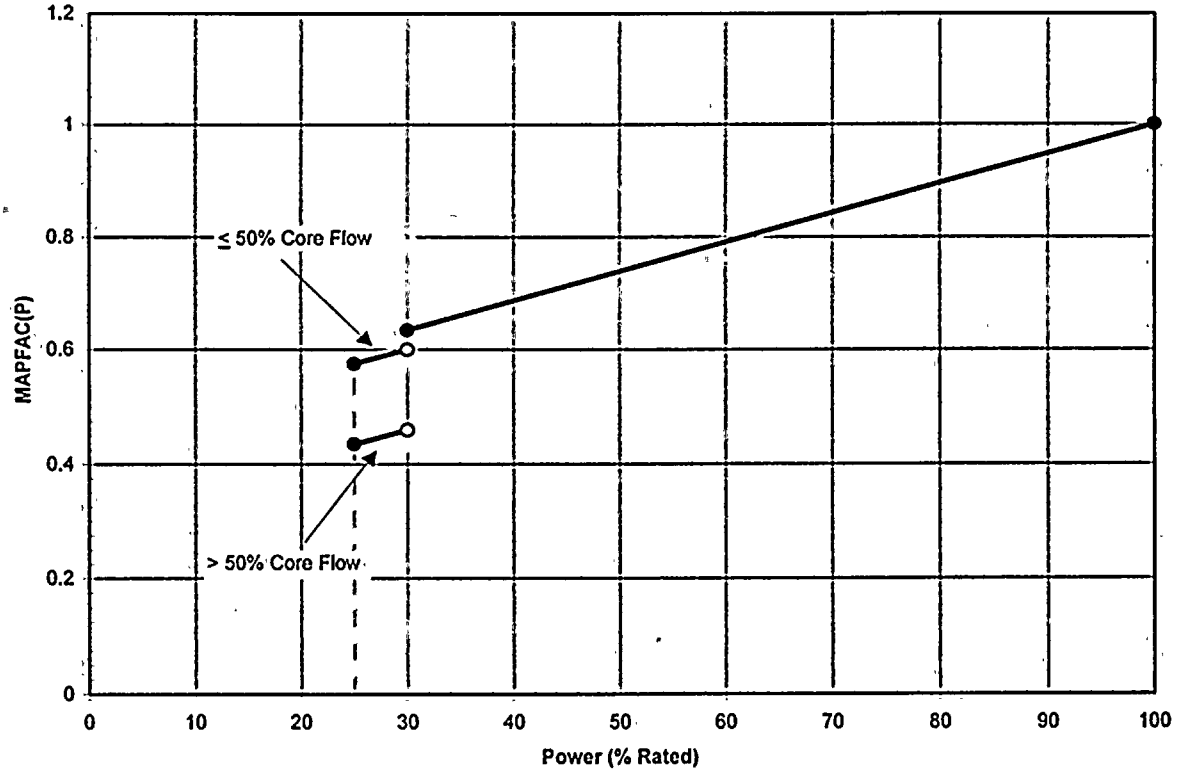
Figure 6
APLHGR Limits for Bundle Type BP8DRB284L
(GE7B)



Average Planar Exposure (GWD/ST)	LHGR Limit (kw/ft)	Average Planar Exposure (GWD/ST)	LHGR Limit (kw/ft)	Average Planar Exposure (GWD/ST)	LHGR Limit (kw/ft)
0.2	11.2	15.0	12.0	35.0	10.1
1.0	11.3	20.0	11.9	40.0	9.4
5.0	11.8	25.0	11.3	45.0	8.8
10.0	12.0	30.0	10.8		

These values apply to both Turbine Bypass In-Service and Out-Of-Service.

Figure 7
Power Dependent MAPLHGR Factor - MAPFAC(P)



MAPLHGR(P) = MAPFAC(P) x MAPLHGRstd

MAPLHGRstd = Standard MAPLHGR Limits

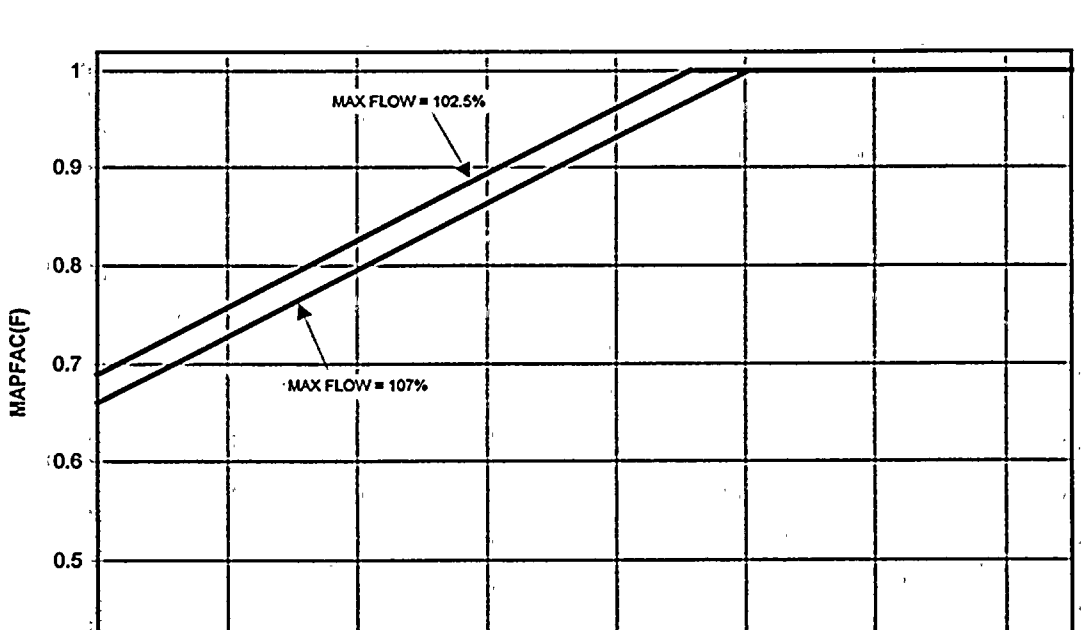
For 25% ≥ P : NO THERMAL LIMITS MONITORING REQUIRED

For 25% ≤ P < 30% : MAPFAC(P) = 0.60 + 0.005(P-30%) For ≤ 50% CORE FLOW
: MAPFAC(P) = 0.46 + 0.005(P-30%) For > 50% CORE FLOW

For 30% ≤ P : MAPFAC(P) = 1.0 + 0.005224(P-100%)

These values bound both Turbine Bypass In-Service and Out-Of-Service

Figure 8
Flow Dependent MAPLHGR Factor - MAPFAC(F)



MAPLHGR(F) = MAPFAC(F) x MAPLHGRstd

MAPLHGRstd = Standard MAPLHGR Limits

MAPFAC(F) = MINIMUM(1.0 , Af * Wc /100 + Bf)

Wc = % Rated Core Flow

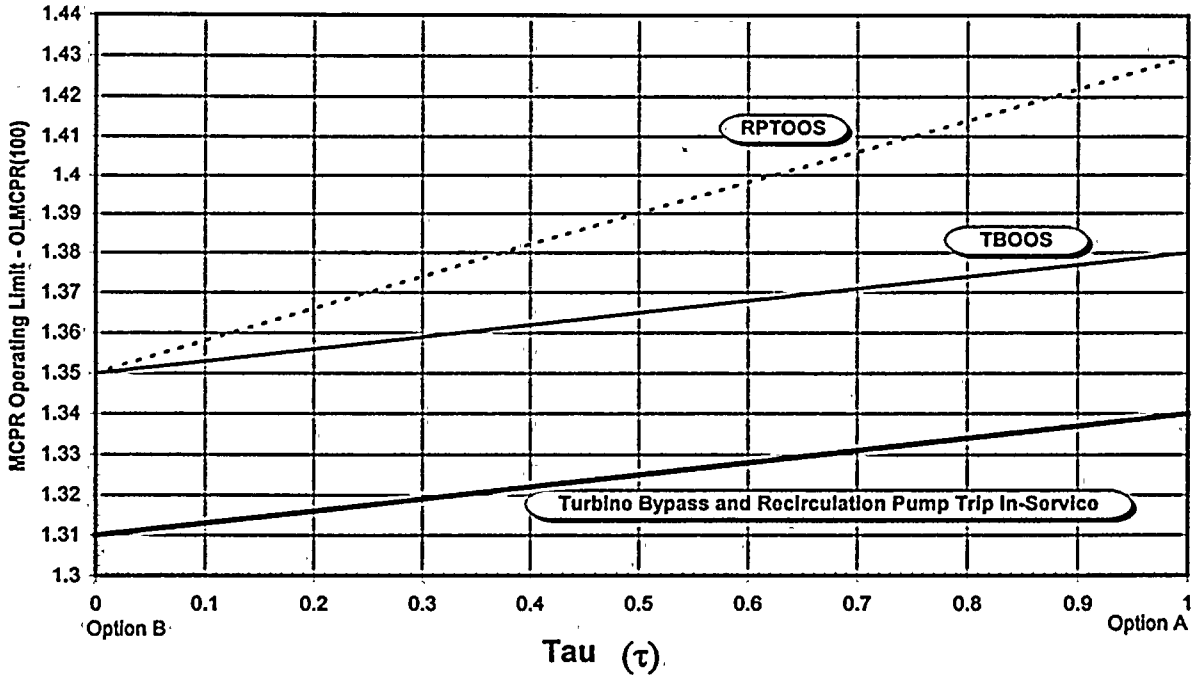
Af and Bf are Constants Given Below:

Maximum Core Flow (% Rated)	Af	Bf
102.5	0.6784	0.4861
107.0	0.6758	0.4574

These values bound both Turbine Bypass In-Service and Out-Of-Service.

The 102.5% maximum flow line is used for operation up to 100% rated flow.
The 107% maximum flow line is used for operation up to 105% rated flow (ICF).

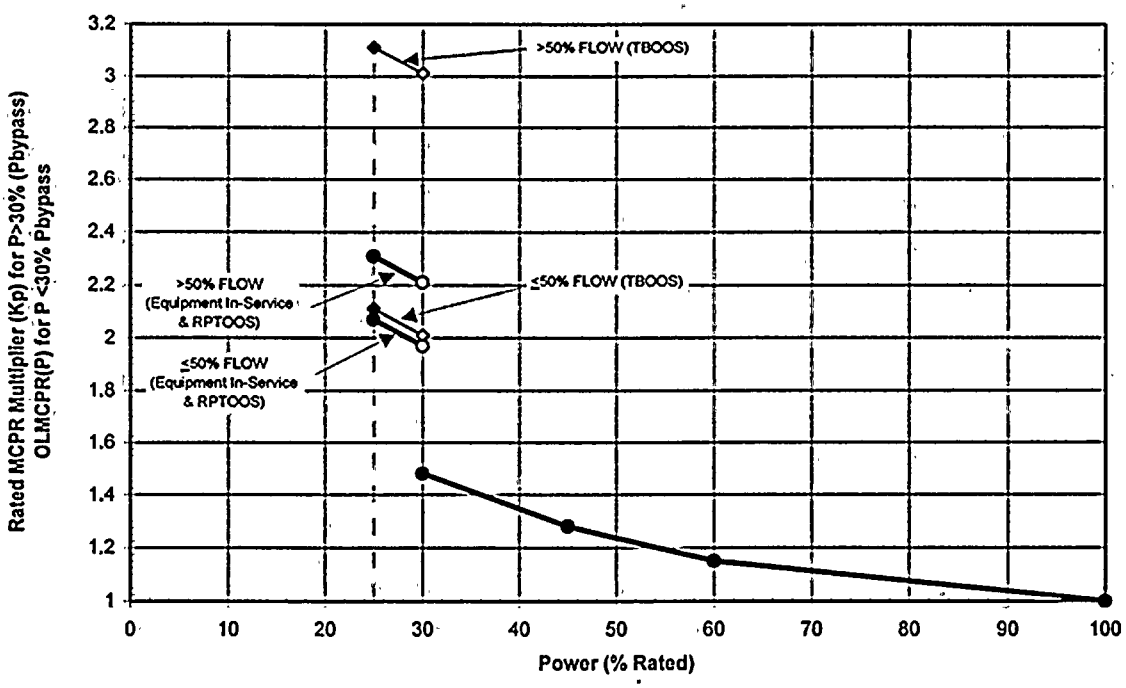
Figure 9
MCPR Operating Limit for All Bundle Types



Exposure Range	Out-Of-Service	Option A Tau=1.0	Option B Tau=0.0
BOC9 to EOC9	na	1.34 (1)	1.31
BOC9 to EOC9	Turbine Bypass (TBOOS)	1.38	1.35
BOC9 to EOC9	Recirculation Pump Trip (RPTOOS)	1.43	1.35

Notes
1. Use this value prior to performing scram time testing per SR 3.1.4.1.
2. Either Turbine Bypass or Recirculation Pump Trip may be Out-Of-Service. The core is not analyzed for both TBOOS and RPTOOS at the same time.

Figure 10
Power Dependent MCPR(P) Limits



OPERATING LIMIT MCPR(P) = Kp * OLMCPR(100)

For P ≤ 25% : NO THERMAL LIMITS MONITORING REQUIRED

For 25% ≤ P < Pbypass : (Pbypass = 30%)

: Kp = [Kbyp + 0.02(30%-P)]/OLMCPR(100)

Turbine Bypass and RPT In-Service,
or RPT Out-Of-Service (RPTOOS)

Kbyp = 1.97 For ≤ 50% CORE FLOW

Kbyp = 2.21 For > 50% CORE FLOW

Turbine Bypass Out-Of-Service (TBOOS)

Kbyp = 2.01 For ≤ 50% CORE FLOW

Kbyp = 3.01 For > 50% CORE FLOW

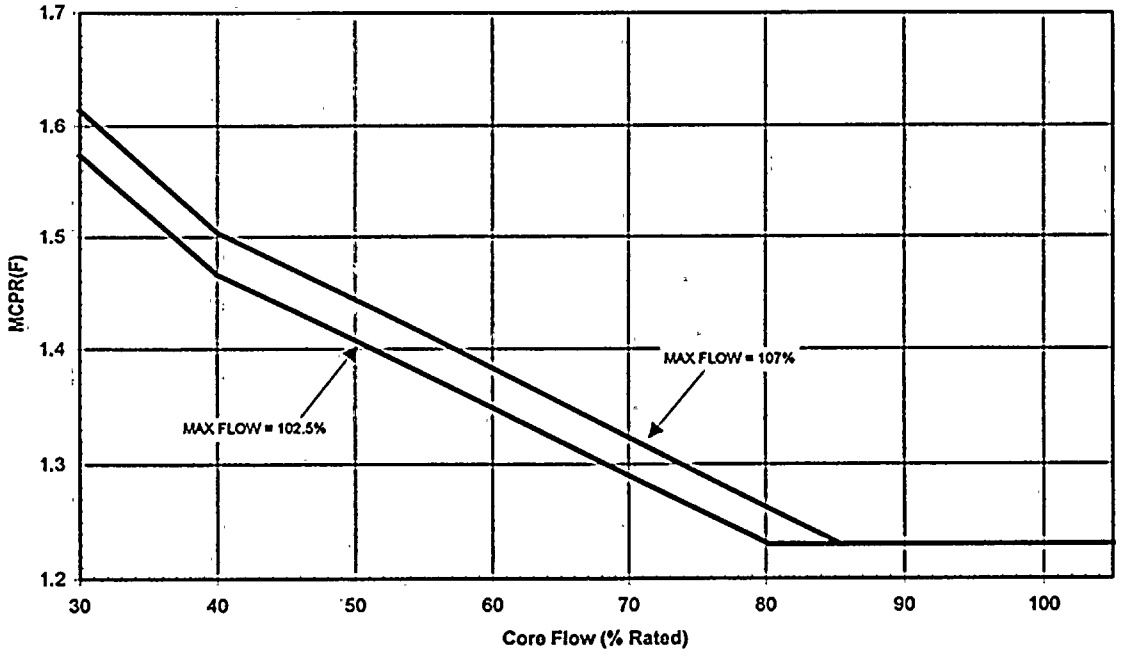
For 30% ≤ P < 45% : Kp = 1.28 + 0.01340(45%-P)

For 45% ≤ P < 60% : Kp = 1.15 + 0.00867(60%-P)

For 60% ≤ P : Kp = 1.00 + 0.00375(100%-P)

Note: Either Turbine Bypass or Recirculation Pump Trip may be Out-Of-Service. The core is not analyzed for both TBOOS and RPTOOS at the same time.

Figure 11
Flow Dependent MCPR Operating Limit - MCPR(F)



For Wc < 40% : MCPR(F) = (Af*Wc/100 + Bf)*[1+0.0032(40-Wc)]

For Wc ≥ 40% : MCPR(F) = MAX(1.23, Af*Wc/100 + Bf)

Wc = % Rated Core Flow

Af and Bf are Constants Given Below:

Maximum Core Flow (% Rated)	Af	Bf
102.5	-0.587	1.701
107.0	-0.603	1.745

These values bound both Turbine Bypass In-Service and Out-Of-Service.

These values bound both Recirculation Pump Trip In-Service and Out-Of-Service

Either Turbine Bypass or Recirculation Pump Trip may be Out-Of-Service.
The core is not analyzed for a combination of TBOOS and RPTOOS.

The 102.5% maximum flow line is used for operation up to 100% rated flow.
The 107% maximum flow line is used for operation up to 105% rated flow (ICF).