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April 28, 2004  
BVY 04-040


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

**Subject: Vermont Yankee Nuclear Power Station  
License No. DPR-28 (Docket No. 50-271)  
Core Operating Limits Report for Cycle 24**

In accordance with Section 6.6.C of the Vermont Yankee Technical Specifications, enclosed is the Core Operating Limits Report (COLR) for Cycle 24. This report presents the cycle-specific operating limits for Cycle 24 of the Vermont Yankee Nuclear Power Station.

If you have any questions concerning this transmittal, please contact Mr. Jeffrey T. Meyer at (802) 258-4105.

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Enclosure

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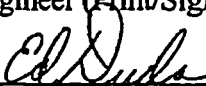

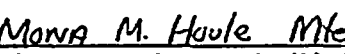
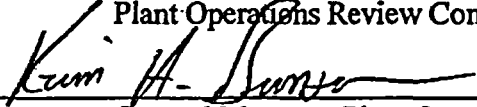
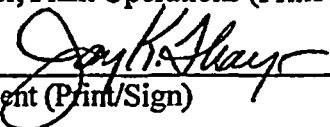
Vermont Yankee Nuclear Power Station

Cycle 24

Core Operating Limits Report

Revision 0

April 2004

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REVISION RECORD

<u>Cycle</u>	<u>Revision</u>	<u>Date</u>	<u>Description</u>
24	0	04/2004	Cycle 24 revision.

## ABSTRACT

This report presents cycle-specific operating limits for the operation of Cycle 24 of the Vermont Yankee Nuclear Power Station as specified in Technical Specification 6.6.C. The limits included in the report are average planar linear heat generation rate, linear heat generation rate, minimum critical power ratio, and thermal-hydraulic stability exclusion region.

The requirement of Technical Specifications Table 3.2.5 pertaining to the rod block monitor (RBM) setpoint equation maximum value of N and maximum allowable RBM rod block setpoint limit are included in this report.

TABLE OF CONTENTS

	<u>Page</u>
LIST OF TABLES .....	ii
LIST OF FIGURES .....	iii
1.0 INTRODUCTION .....	1
2.0 CORE OPERATING LIMITS .....	2
2.1 Average Planar Linear Heat Generation Rate Limits (APLHGR).....	2
2.2 Minimum Critical Power Ratio (MCPR) Limits .....	2
2.3 Linear Heat Generation Rate (LHGR) Limits .....	4
2.4 Thermal-Hydraulic Stability Exclusion Region.....	5
2.5 Power/Flow Map.....	8
2.6 Single Loop Operation.....	8
2.7 Rod Block Monitoring .....	9
REFERENCES .....	20

TABLE OF CONTENTS (Continued)

LIST OF TABLES

<u>Number</u>	<u>Title</u>	<u>Page</u>
Table 2.1-1	MAPLHGR Limits for GE14-P10DNAB426-16G6.0-100T-150-T6-2682 Fuel Bundle No. 2682.....	9
Table 2.1-2	MAPLHGR Limits for GE14-P10DNAB390-14GZ-100T-150-T6-2683 Fuel Bundle No. 2683.....	9
Table 2.1-3	MAPLHGR Limits for GE14-P10DNAB388-17GZ-100T-150-T6-2684 Fuel Bundle No. 2684.....	10
Table 2.1-4	MAPLHGR Limits for GE9B-P8DWB335-10GZ-80U-150-T6 Fuel Bundle No. 3615.....	10
Table 2.1-5	MAPLHGR Limits for GE9B-P8DWB335-11GZ-80U-150-T6 Fuel Bundle No. 3616.....	11
Table 2.1-6	MAPLHGR Limits for GE13-P9DTB386-11G4.0/1G3.0-100T-146-T6-3958 Fuel Bundle No. 3958.....	11
Table 2.1-7	MAPLHGR Limits for GE13-P9DTB225-NOG-100T-146-T6-2571 Fuel Bundle No. 2571.....	12
Table 2.1-8	MAPLHGR Limits for GE14-P10DNAB394-7G5.0/6G4.0-100T-150-T6-2566 Fuel Bundle No. 2566.....	12
Table 2.1-9	MAPLHGR Limits for GE14-P10DNAB394-8G5.0/6G4.0-100T-150-T6-2595 Fuel Bundle No. 2595.....	13
Table 2.1-10	MAPLHGR Limits for GE14-P10DNAB394-12G5.0-100T-150-T6-2596 Fuel Bundle No. 2596.....	13
Table 2.2-1	Cycle 24 Rated MCPR Operating Limits (OLMCPR).....	14
Table 2.2-2	RBM Setpoint.....	14

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

<u>Number</u>	<u>Title</u>	<u>Page</u>
2.2-1	Power Dependent K (P) / MCPR (P) Limits.....	15
2.2-2	Flow Dependent MCPR Operating Limit MCPR (F).....	16
2.3-1	Power Dependent LHGRFAC (P) Multiplier .....	17
2.3-2	LHGR Flow Factor LHGRFAC (F).....	18
2.4-1	Limits of Power/Flow Operation .....	19

## 1.0 INTRODUCTION

This report provides the cycle-specific limits for operation of the Vermont Yankee Nuclear Power Station in Cycle 24. It includes the limits for the average planar linear heat generation rate, linear heat generation rate, minimum critical power ratio, and thermal-hydraulic stability exclusion region. If any of these limits are exceeded, action will be taken as defined in the Technical Specifications.

As specified in Technical Specifications Table 3.2.5, the rod block monitor (RBM) setpoint equation maximum value of N and maximum allowable RBM rod block setpoint limit are included in this report.

This Core Operating Limits report for Cycle 24 has been prepared in accordance with the requirements of Technical Specifications 6.6.C. The core operating limits have been developed using the NRC-approved methodologies listed in References 3.1 through 3.4. The methodologies are also listed in Technical Specification 6.6.C. The bases for these limits are in References 3.5 through 3.10.



## 2.0 CORE OPERATING LIMITS

The Cycle 24 operating limits have been defined using NRC-approved methodologies. Cycle 24 must be operated within the bounds of these limits and all others specified in the Technical Specifications.

### 2.1. Average Planar Linear Heat Generation Rate Limits (APLHGR) (T.S. 3.11.A)

APLHGR is applicable to a specific planar height and is equal to the sum of the linear heat generation rate (LHGR) for all of the fuel rods in the specific bundle at the specific height divided by the number of fuel rods in the fuel bundle at the height.

The maximum APLHGR (MAPLHGR) limit is a function of reactor power, core flow, fuel type, and average planar exposure. The cycle dependent limits are developed using NRC approved methodology described in References 3.1 and 3.3. The MAPLHGR limit ensures that the peak clad temperature during a LOCA will not exceed the limits as specified in 10CFR50.46 (b) (1) and that the fuel design analysis criteria defined in References 3.1 and 3.3 will be met.

Tables 2.1-1 through 2.1-10 provide a limiting composite of MAPLHGR values for each fuel type, which envelope the lattice MAPLHGR values employed by the process computer (Reference 3.6). When hand calculations are required, these MAPLHGR values are used for all lattices in the bundle.

For single recirculation loop operation, the limiting values shall be the values from these Tables listed under the heading "Single Loop Operation." These values are obtained by multiplying the values for two loop operation by 0.82 (Reference 3.6).

### 2.2. Minimum Critical Power Ratio (MCPR) Limits (T.S. 3.11.C)

MCPR is the smallest Critical Power Ratio (CPR) that exists in the core for each type of fuel and shall be equal to, or greater than the Operating Limit MCPR (OLMCPR), which is a function of Core Thermal Power, Core Flow, Fuel Type, and Scram Time (Tau).

The rated Operating Limit MCPR at steady-state rated power and increased core flow operating conditions is derived from the cycle specific fuel cladding integrity Safety Limit MCPR and the delta CPR, as determined from the most limiting transient event. The rated OLMCPR will ensure that the Safety Limit MCPR is not exceeded during any abnormal operational occurrence (AOC) (Reference 3.6).

The rated OLMCPR for two loop and single loop operation is documented in Table 2.2-1 and is dependent on scram time (Tau) surveillance data at position 36 (Reference 3.8).

Determination of Tau:

- i. First,  $\tau_{ave}$  shall be determined:

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

where:

$n$  = number of scram time tests thus far this cycle,

$N_i$  = number of active rods measured in surveillance  $i$ , and

$\tau_i$  = average scram time to position 36 dropout of all rods measured in surveillance  $i$ .

- ii. Second,  $\tau_B$  shall be determined:

$$\tau_B = \mu + 1.65 \sqrt{\left[ \frac{N_1}{\sum_{i=1}^n N_i} \right] \sigma}$$

where:

$\mu = 0.830$  = mean of the distribution for average scram insertion time to position 36 dropout used in the ODYN Option B analysis.

$\sigma = 0.019$  = standard deviation of the distribution for average scram insertion time to position 36 dropout used in the ODYN Option B analysis.

$N_1$  = number of active rods measured during the first surveillance test at BOC.

- iii. Third, determine the OLMCPR, as follows:

If  $\tau_{ave} \leq \tau_B$ , then  $OLMCPR_{Option B}$  from Table 2.2.1 may be used.

If  $\tau_{ave} > \tau_B$ , then a new OLMCPR shall be calculated:

$$OLMCPR_{New} = OLMCPR_{Option B} + \frac{\tau_{ave} - \tau_B}{\tau_A - \tau_B} (OLMCPR_{Option A} - OLMCPR_{Option B})$$

where:

$OLMCPR_{Option\ A}$  = Option A OLMCPR from Table 2.2.1 based on Option A analysis using full core scram times listed in Technical Specification 3.3.C.1.2.

$OLMCPR_{Option\ B}$  = Option B OLMCPR from Table 2.2.1 based on Option B analysis described in Reference 3.1.

$\tau_4$  = 1.096 seconds = Technical Specification 3.3.C.1.2 core average scram time to drop-out of position 36.

The OLMCPR is the greater of the flow and power dependent MCPR operating limits, MCPR (F) and MCPR (P).

$$OLMCPR = MAX (MCPR (P), MCPR (F))$$

The flow dependent MCPR operating limits, MCPR (F), is provided in Figure 2.2-2.

For core thermal powers less than or equal to 30%, the power dependent MCPR operating limit, MCPR (P), is provided in Figure 2.2-1. Above 30%, MCPR (P) is the product of the rated OLMCPR presented in Table 2.2-1 and the K (P) factor presented in Figure 2.2-1.

Cycle exposure dependent limits are provided through the end of rated exposure point, which is expected to be the maximum exposure attainable at full power during ICF operation. Coastdown operation is allowable down to 40% rated CTP.

For single recirculation loop operation, the MCPR limits at rated flow shall be the values from Table 2.2-1 listed under the heading, "Single Loop Operation." The single loop values are obtained by adding 0.02 to the two loop operation values (TS 1.1.A.1).

### 2.3. Linear Heat Generation Rate (LHGR) Limits (T.S. 3.11.B)

LHGR is the heat generation rate per unit length of fuel rod. It is the integral of the heat flux over the heat transfer area associated with the unit length. By maintaining the operating LHGR below the applicable LHGR limit, it is assured that all thermal-mechanical design basis and licensing limits for the fuel will be satisfied.

The maximum LHGR limit is a function of reactor power, core flow, fuel and rod type, and fuel rod nodal exposure. The limit is developed using NRC approved methodology described in Reference 3.1 to ensure the cladding will not exceed its yield stress and that the fuel thermal-mechanical design criteria will not be violated during any postulated transient events.

During reactor power operation, the LHGR of any rod in any fuel bundle at any axial location shall not exceed the rated power and rated core flow limits (LHGR<sub>std</sub>) for each fuel and rod type as a function of fuel rod nodal exposure listed in Reference 3.7.

The LHGR limits for the fuel pin axial locations with no gadolinium and maximum gadolinium concentration listed in Reference 3.7 are expected to operate near the LHGR limits.

There are also fuel pins with axial locations that have gadolinium concentrations that are less than the maximum concentration anywhere in the bundle. The LHGR limits for these axial locations range uniformly between the case of no gadolinium and the most limiting gadolinium concentration and are listed in Reference 3.9.

For other than rated power and flow conditions (below 25% core thermal power thermal limit calculation is not required), the applicable limiting LHGR values for each fuel type is the smaller of the power and flow dependent LHGR limits multiplied by the applicable power and flow adjustment factor or the LHGR limit multiplied by 0.82 when in single loop operation.

$$\text{LHGR limit} = \text{MIN} (\text{LHGR} (P), \text{LHGR} (F)).$$

Power-dependent LHGR limit, LHGR (P), is the product of the LHGR power dependent LHGR limit adjustment factor, LHGRFAC (P), shown in Figure 2.3-1 and the LHGR<sub>std</sub>.

$$\text{LHGR} (P) = \text{LHGRFAC} (P) \times \text{LHGR}_{\text{std}}$$

The flow-dependent LHGR limit, LHGR (F), is the product of the LHGR flow dependent LHGR limit adjustment factor, LHGRFAC (F), shown in Figure 2.3-2 and the LHGR<sub>std</sub>.

$$\text{LHGR} (F) = \text{LHGRFAC} (F) \times \text{LHGR}_{\text{std}}$$

#### 2.4. Thermal-Hydraulic Stability Exclusion Region (T.S. 3.6.J)

For Cycle 24, based on decay ratios at the most limiting point on the power/flow, the predominate oscillation mode is core-wide. Normal plant operation is not allowed inside the bounds of the exclusion region defined in Figure 2.4-1. These power and flow limits are applicable for Cycle 24. Operation inside of the exclusion region may result in a thermal-hydraulic oscillation. Intentional operation within the buffer region is not allowed unless the Stability Monitor is operable. Otherwise, the buffer region is considered part of the exclusion region (Reference 3.6).

The coordinates of the Exclusion Region are as follows:

Point	Power (%)	Flow (%)
A	77.4	50.0
B	45.0	31.3

The equation for the boundary is as follows:

$$P = P_B \left( \frac{P_A}{P_B} \right)^{\frac{1}{2}} \left[ \frac{W - W_B}{W_A - W_B} + \left( \frac{W - W_B}{W_A - W_B} \right)^2 \right]$$

where,

- P = a core thermal power value on the Exclusion Region boundary (% of rated),
- W = the core flow rate corresponding to power, P, on the Exclusion Region boundary (% of rated),
- P<sub>A</sub> = core thermal power at State Point A (% of rated),
- P<sub>B</sub> = core thermal power at State Point B (% of rated),
- W<sub>A</sub> = core flow rate at State Point A (% of rated),
- W<sub>B</sub> = core flow rate at State Point B (% of rated),

The range of validity of the fit is: 31.3% ≤ %Flow ≤ 50.0%

The coordinates of the Buffer Region are as follows:

Point	Power (%)	Flow (%)
C	81.8	55.0
D	40.0	31.3

The generic equation used to generate the 5% buffer zone exclusion region boundary is:

$$P = P_D \left( \frac{P_C}{P_D} \right)^{\frac{1}{2}} \left[ \frac{W - W_D}{W_C - W_D} + \left( \frac{W - W_D}{W_C - W_D} \right)^2 \right]$$

where,

- P = a core thermal power value on the Buffer Zone boundary (% of rated),
- W = the core flow rate corresponding to power, P, on the 5% Buffer Zone boundary (% of rated),
- P<sub>C</sub> = core thermal power at State Point C (% of rated),
- P<sub>D</sub> = core thermal power at State Point D (% of rated),
- W<sub>C</sub> = core flow rate at State Point C (% of rated),
- W<sub>D</sub> = core flow rate at State Point D (% of rated),

The range of validity of the fit is: 31.3% ≤ %Flow ≤ 55.0%.

## 2.5. Power/Flow Map

Power operation, with respect to Core Thermal Power/Total Core Flow combinations, is allowed within the boldly outlined area of Figure 2.4-1. This area is bounded by the following lines:

- **Minimum Pump Speed Line;** This line approximates operation at minimum pump speed. Plant start-up is performed with the recirculation pumps operating at approximately 20% speed. Reactor power level will approximately follow this line during the normal control rod withdrawal sequence.
- **Minimum Power Line;** This line approximates the interlock that requires recirc pump speed to be at a minimum below 20% of feedwater flow. This interlock ensures NPSH requirements are met.
- **Natural Circulation Line;** The operating state the reactor follows along this line for the normal control rod withdrawal sequence in the absence of recirculation pump operation.
- **Exclusion Region -** The exclusion region is a power/flow region where an instability can occur. The boundary for the exclusion region is established through use of an analysis procedure which is demonstrated to be conservative relative to expected operating conditions.
- **5% Buffer Region Boundary;** The Buffer Region is determined by adjusting the endpoints of the Exclusion Region and increasing the flow on the highest rod line by 5% and decreasing power on the natural circulation line by 5%.
- **Rated Power Line and MELLLA Boundary;** These lines provide the upper power limit and operating domain assumed in transient analyses.
- **ICF Boundary;** This line represents the highest allowable analyzed core flow. The analysis in Reference 3.4 supports the maximum attainable core flow being approximately 107% of rated core flow.
- **108% rod line;** this line represents the ELLLA operating boundary and is the maximum load line allowed in single loop operation.

## 2.6. Single Loop Operation

SLO was not analyzed for operation in the MELLLA region. The power/flow operating condition for Single Loop Operation (SLO) is core power less than 1239 MWTh (77.77%CTP), core flow less than 26.35 M#/hr (54.9%) and maximum rod line less than 108%. (References 3.2 and 3.11)

2.7. Rod Block Monitoring

The rod block monitor (RBM) setpoint equation maximum value of N and maximum allowable RBM rod block setpoint limit are listed in Table 2.2-2.

Table 2.1-1

MAPLHGR Limits for GE14-P10DNAB426-16G6.0-100T-150-T6-2682  
Fuel Bundle No. 2682

Average Planar Exposure (GWd/ST)	MAPLHGR (kW/ft)	
	Two Loop Operation	Single Loop Operation <sup>1</sup>
0.00	12.82	10.51
19.12	12.82	10.51
57.61	8.00	6.56
63.50	5.00	4.10

Technical Specification References: 3.6.G.1a and 3.11.A.

<sup>1</sup> MAPLHGR for single loop operation is obtained by multiplying MAPLHGR for two loop operation by 0.82.

Table 2.1-2

MAPLHGR Limits for GE14-P10DNAB390-14GZ-100T-150-T6-2683  
Fuel Bundle No. 2683

Average Planar Exposure (GWd/ST)	MAPLHGR (kW/ft)	
	Two Loop Operation	Single Loop Operation <sup>1</sup>
0.00	12.82	10.51
19.12	12.82	10.51
57.61	8.00	6.56
63.50	5.00	4.10

Technical Specification References: 3.6.G.1a and 3.11.A.

<sup>1</sup> MAPLHGR for single loop operation is obtained by multiplying MAPLHGR for two loop operation by 0.82.



Table 2.1-3

MAPLHGR Limits for GE14-P10DNAB388-17GZ-100T-150-T6-2684  
Fuel Bundle No. 2684

Average Planar Exposure (GWd/ST)	MAPLHGR (kW/ft)	
	Two Loop Operation	Single Loop Operation <sup>1</sup>
0.00	12.82	10.51
19.12	12.82	10.51
57.61	8.00	6.56
63.50	5.00	4.10

Technical Specification References: 3.6.G.1a and 3.11.A.

<sup>1</sup> MAPLHGR for single loop operation is obtained by multiplying MAPLHGR for two loop operation by 0.82.

Table 2.1-4

MAPLHGR Limits for GE9B-P8DWB335-10GZ-80U-150T-T6  
Fuel Bundle No. 3615

Average Planar Exposure (GWd/ST)	MAPLHGR (kW/ft)	
	Two Loop Operation	Single Loop Operation <sup>1</sup>
0.00	13.90	11.39
16.58	13.90	11.39
48.08	9.20	7.54
54.43	6.00	4.92

Technical Specification References: 3.6.G.1a and 3.11.A.

<sup>1</sup> MAPLHGR for single loop operation is obtained by multiplying MAPLHGR for two loop operation by 0.82.

Table 2.1-5

MAPLHGR Limits for GE9B-P8DWB335-11GZ-80U-150T-T6  
Fuel Bundle No. 3616

Average Planar Exposure (GWd/ST)	MAPLHGR (kW/ft)	
	Two Loop Operation	Single Loop Operation <sup>1</sup>
0.00	13.90	11.39
16.58	13.90	11.39
48.08	9.20	7.54
54.43	6.00	4.92

Technical Specification References: 3.6.G.1a and 3.11.A.

<sup>1</sup> MAPLHGR for single loop operation is obtained by multiplying MAPLHGR for two loop operation by 0.82.

Table 2.1-6

MAPLHGR Limits for GE13-P9DTB386-11G4.0/1G3.0-100T-146-T6-3958  
Fuel Bundle No. 3958

Average Planar Exposure (GWd/ST)	MAPLHGR (kW/ft)	
	Two Loop Operation	Single Loop Operation <sup>1</sup>
0.00	13.40	10.98
13.24	13.40	10.98
21.77	13.20	10.82
26.95	13.20	10.82
32.66	12.70	10.41
56.70	9.00	7.38
63.50	6.40	5.24

Technical Specification References: 3.6.G.1a and 3.11.A.

<sup>1</sup> MAPLHGR for single loop operation is obtained by multiplying MAPLHGR for two loop operation by 0.82.

Table 2.1-7

MAPLHGR Limits for GE13-P9DTB225-NOG-100T-146-T6-2571  
Fuel Bundle No. 2571

Average Planar Exposure (GWd/ST)	MAPLHGR (kW/ft)	
	Two Loop Operation	Single Loop Operation <sup>1</sup>
0.00	13.40	10.98
13.24	13.40	10.98
21.77	13.20	10.82
26.95	13.20	10.82
32.66	12.70	10.41
56.70	9.00	7.38
63.50	6.40	5.24

Technical Specification References: 3.6.G.1a and 3.11.A.

<sup>1</sup> MAPLHGR for single loop operation is obtained by multiplying MAPLHGR for two loop operation by 0.82.

Table 2.1-8

MAPLHGR Limits for GE14-P10DNAB394-7G5.0/6G4.0-100T-150-T6-2566  
Fuel Bundle No. 2566

Average Planar Exposure (GWd/ST)	MAPLHGR (kW/ft)	
	Two Loop Operation	Single Loop Operation <sup>1</sup>
0.00	12.82	10.51
19.12	12.82	10.51
57.61	8.00	6.56
63.50	5.00	4.10

Technical Specification References: 3.6.G.1a and 3.11.A.

<sup>1</sup> MAPLHGR for single loop operation is obtained by multiplying MAPLHGR for two loop operation by 0.82.

Table 2.1-9

MAPLHGR Limits for GE14-P10DNAB394-8G5.0/6G4.0-100T-150-T6-2595  
Fuel Bundle No. 2595

Average Planar Exposure (GWd/ST)	MAPLHGR (kW/ft)	
	Two Loop Operation	Single Loop Operation <sup>1</sup>
0.00	12.82	10.51
19.12	12.82	10.51
57.61	8.00	6.56
63.50	5.00	4.10

Technical Specification References: 3.6.G.1a and 3.11.A.

<sup>1</sup> MAPLHGR for single loop operation is obtained by multiplying MAPLHGR for two loop operation by 0.82.

Table 2.1-10

MAPLHGR Limits for GE14-P10DNAB394-12G5.0-100T-150-T6-2596  
Fuel Bundle No. 2596

Average Planar Exposure (GWd/ST)	MAPLHGR (kW/ft)	
	Two Loop Operation	Single Loop Operation <sup>1</sup>
0.00	12.82	10.51
19.12	12.82	10.51
57.61	8.00	6.56
63.50	5.00	4.10

Technical Specification References: 3.6.G.1a and 3.11.A.

<sup>1</sup> MAPLHGR for single loop operation is obtained by multiplying MAPLHGR for two loop operation by 0.82.

Table 2.2-1

Cycle 24 Rated MCPR Operating Limits (OLMCPR)

Option	Cycle Exposure <u>Range</u>	Two Loop <u>Operation</u> <sup>2</sup>	Single Loop <u>Operation</u> <sup>1</sup>
Option A	0 to 11915 MWd/St	1.60	1.62
Option B	0 to 11915 MWd/St	1.43	1.45

Source: References 3.6 and 3.7.

- 1 The MCPR operating limit is increased by 0.02 for single loop operation.
- 2 The two loop MCPR operating limits bound ICF operation throughout the cycle.

Table 2.2-2  
RBM Setpoint<sup>3</sup>

Maximum Value of "N" in RBM Setpoint Equation – 62.

Maximum Allowable RBM Rod Block setpoint – 112% power.

Source: Reference 3.10

Technical Specification References: Table 3.2.5.

- 3 The Rod Block Monitor (RBM) trip setpoints are determined by the equation shown in Table 3.2.5 of the Technical Specifications.

Power Dependent K (P) / MCPR (P) Limits

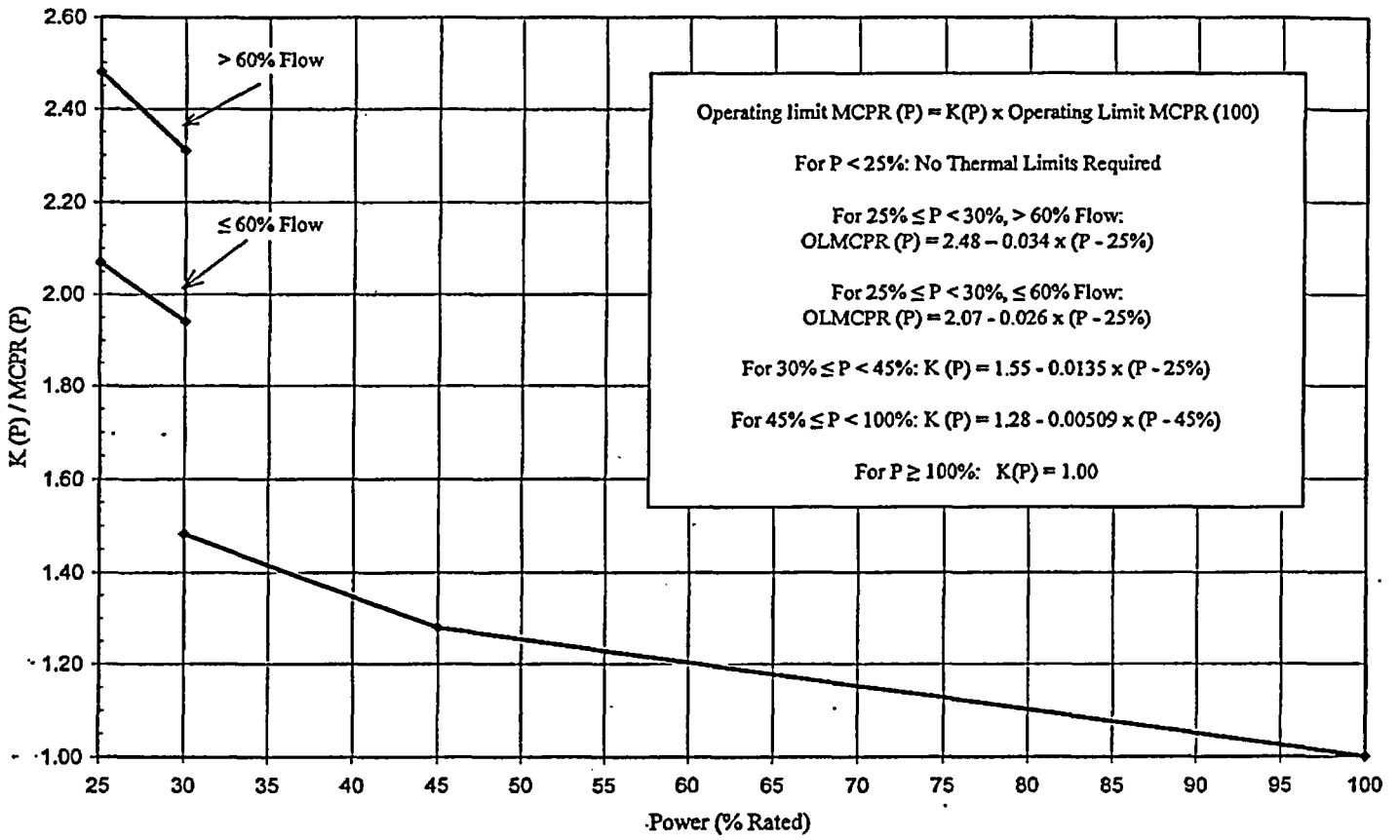
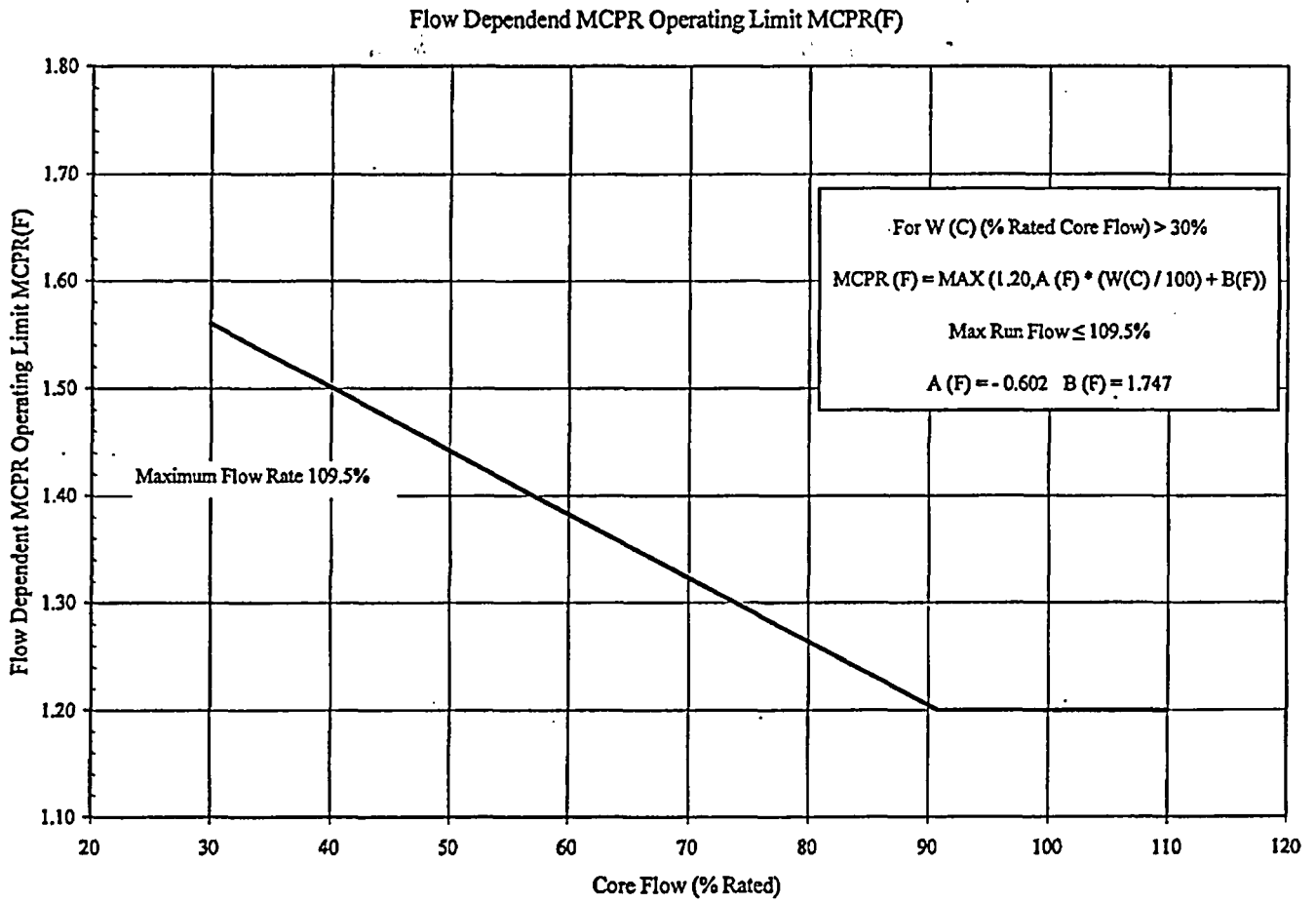


Figure 2.2-1

Power Dependent K (P) / MCPR (P) Limits  
 (Technical Specification Reference 3.11.C)



Power Dependant LHGRFAC(P) Multiplier

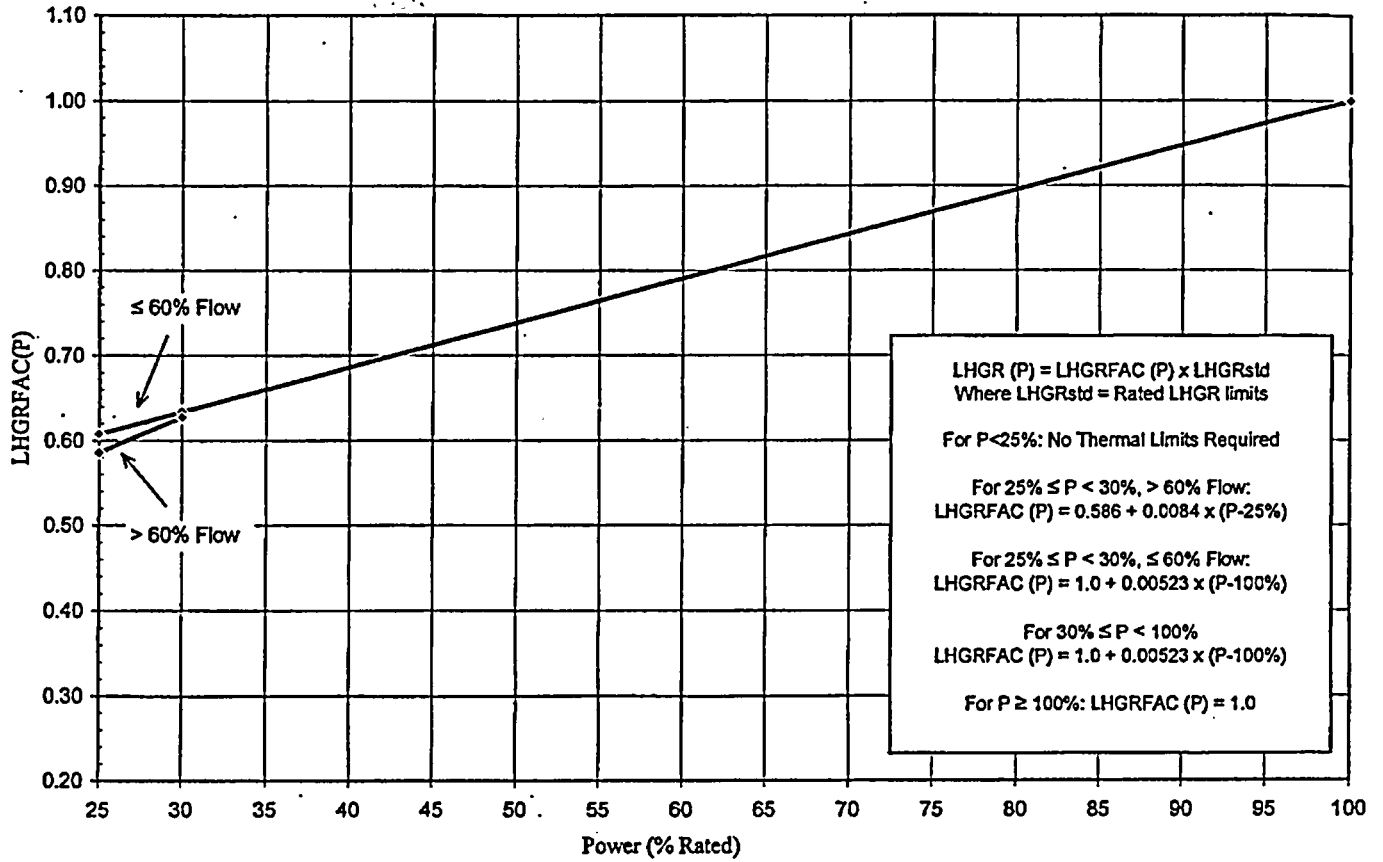
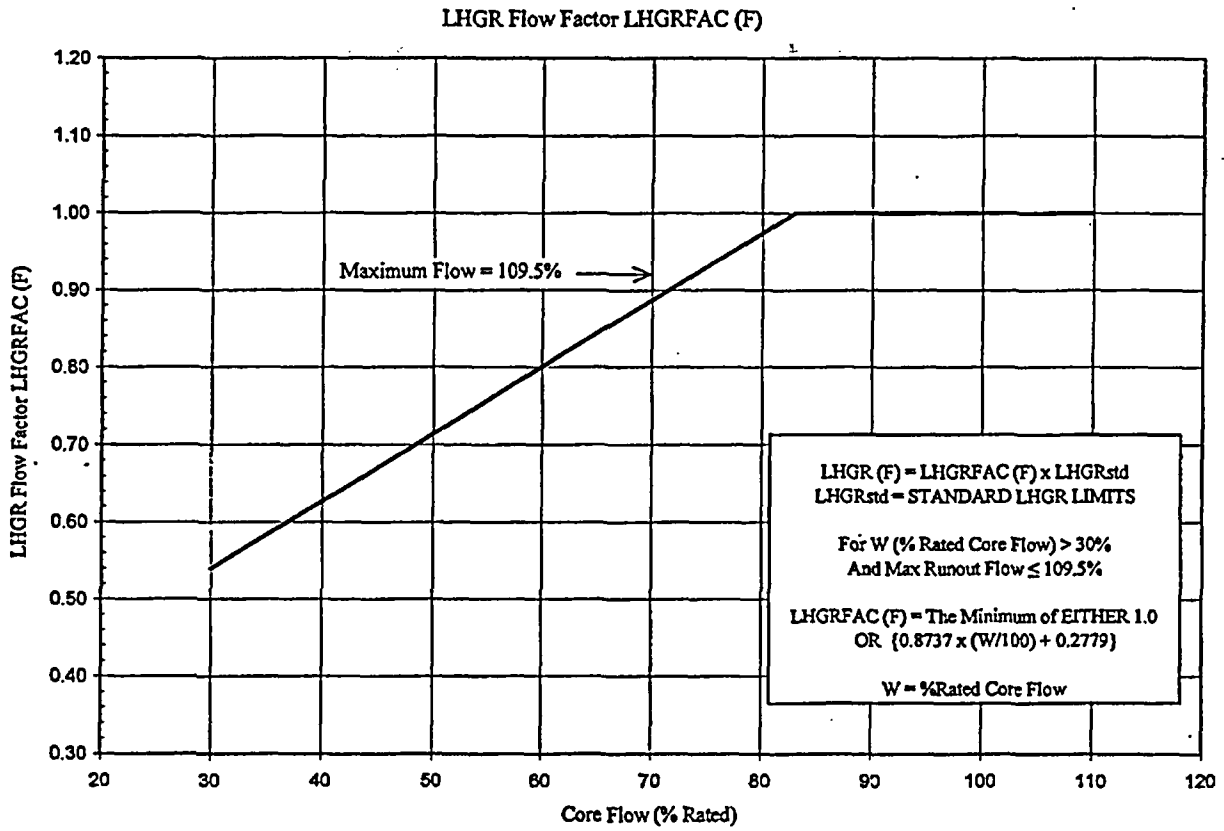


Figure 2.3-1

Power Dependent LHGRFAC (P) Multiplier  
(Technical Specification Reference 3.11.B)





**Figure 2.3-2**

**LHGR Flow Factor LHGRFAC (F)**  
**(Technical Specification Reference 3.11.B)**

Cycle 24 Power/Flow Map

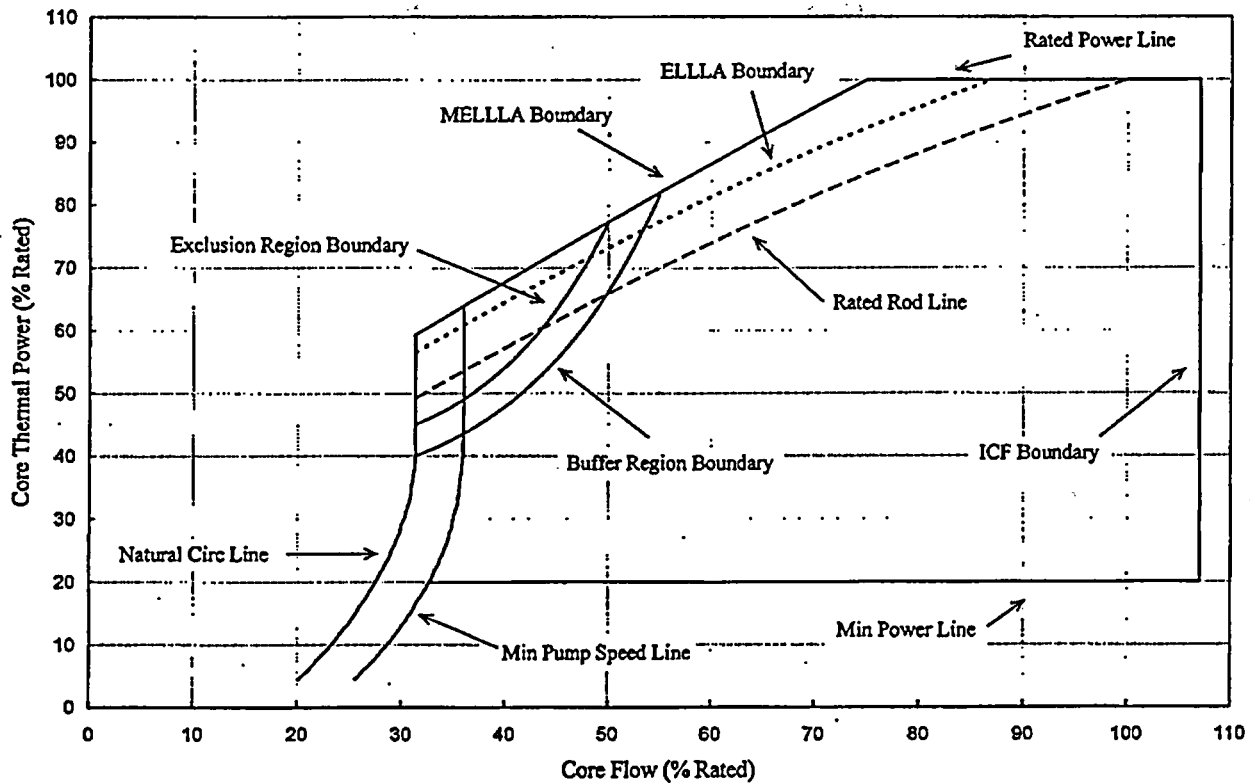


Figure 2.4-1

Limits of Power/Flow Operation  
(Technical Specification Reference 3.6.J)

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