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October 28, 2011

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

SUBJECT: Cycle 29, Core Operating Limits Report Update
Vermont Yankee Nuclear Power Station
Docket No. 50-271
License No. DPR-28

Dear Sir or Madam:

In accordance with Section 6.6.C of the Vermont Yankee Technical Specifications, enclosed is the Cycle 29, Core Operating Limits Report. This report updates the cycle-specific operating limits for Cycle 29 for the Vermont Yankee Nuclear Power Station.

There are no regulatory commitments being made in this submittal.

Should you have any questions concerning this transmittal, please contact me at (802) 451-3166.

Sincerely,

[RJW/JMD]

Attachment 1 – Vermont Yankee Nuclear Power Station, Cycle 29 Core Operating Limits Report

cc listing (next page)

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Vermont Yankee Nuclear Power Station

Cycle 29

Core Operating Limits Report

Revision 0

REVISION RECORD

Revision	Revision Description
0	Initial issue.

ABSTRACT

This report presents Cycle 29 specific operating limits at current license thermal power for the operation 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 for single loop and dual loop operation are also included in this report.

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1.0 INTRODUCTION

The Core Operating Limits Report (COLR) provides cycle-specific limits for operation of the Vermont Yankee Nuclear Power Station reactor core. 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 for single and dual loop operation are included in this report.

This COLR for Cycle 29 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 3.8.

As documented in the Vermont Yankee Extended Power Uprate (EPU) Safety Evaluation and resulting License Condition (Reference 3.10), when operating at thermal power greater than 1593 megawatts thermal, the safety limit minimum critical power ratio (SLMCPR) shall be established by adding 0.02 to the cycle-specific SLMCPR value calculated by the NRC approved methodologies documented in General Electric Licensing Topical Report NEDE-24011-P-A, "General Electric Standard Application for Reactor Fuel," as amended and documented in the COLR. The 0.02 penalty is not applied to the single loop SLMCPR, because the plant is limited to the conditions specified in Section 2.6 while in single loop operation. The reload licensing analysis is consistent with the SLMCPR in Technical Specification 1.1.A (1.09 dual loop and 1.10 single loop) and includes the imposed license condition on the dual loop value (Reference 3.6).

2.0 CORE OPERATING LIMITS

The Cycle 29 operating limits have been defined using NRC-approved methodologies. Cycle 29 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, 3.3 and 3.11. 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, 3.3 and 3.11 will be met.

Tables 2.1-1 and 2.1-2 provide the MAPLHGR values for each fuel type (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 (References 3.6 and 3.9).

The power and flow dependent LHGR limits (LHGRFAC multipliers) in Figure 2.3-1 and 2.3-2 are sufficient to provide adequate protection for off-rated conditions for a LOCA. Therefore, the power and flow dependent MAPFAC multipliers are set to unity.

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, Cycle Exposure, 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 (AOO) (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 3.5).

Determination of Tau:

i. First, τ_{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

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

ii. Second, τ_B shall be determined:

$$\tau_B = \mu + 1.65 \sqrt{\frac{N_1}{\sum_{i=1}^{n} N_i}}\,\sigma$$

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:

$$\mathrm{OLMCPR}_{\mathrm{New}} = \mathrm{OLMCPR}_{\mathrm{Option\ B}} + \frac{\tau_{ave} - \tau_B}{\tau_A - \tau_B}\left(\mathrm{OLMCPR}_{\mathrm{Option\ A}} - \mathrm{OLMCPR}_{\mathrm{Option\ B}}\right)$$

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 Specifications.

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

τ_A = 1.096 seconds = Technical Specification 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 limit, MCPR (F), is provided in Figure 2.2-2.

For core thermal power less than 25%, the power dependent MCPR operating limit, MCPR (P), is provided in Figure 2.2-1. For core thermal power equal to or greater than 25%, 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 per Reference 3.1.

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 0.01 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 ($LHGR_{std}$) 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.

For other than rated power and flow conditions (below 23% 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.

LHGR limit = MIN (LHGR (P), 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 $LHGR_{std}$.

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

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 $LHGR_{std}$.

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

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

The predominant oscillation mode is core-wide based on decay ratios at the most limiting point on the power/flow map. Normal plant operation is not allowed inside the bounds of the exclusion region defined in Figure 2.4-1. 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	58.9	43.0
B	36.0	31.3

The Modified Shape Function equation used to generate the Exclusion Region boundary is as follows:

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

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_A = core thermal power at State Point A (% of rated),
P_B = core thermal power at State Point B (% of rated),
W_A = core flow rate at State Point A (% of rated),
W_B = core flow rate at State Point B (% of rated),

The range of validity of the fit is: $31.3\% \leq \%\text{Flow} \leq 43.0\%$

The coordinates of the Buffer Region are as follows:

Point	Power (%)	Flow (%)
C	65.3	51.0
D	31.0	31.2

The Modified Shape Function equation used to generate the Buffer Region boundary is as follows:

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

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 Buffer Zone boundary (% of rated),
P_C	=	core thermal power at State Point C (% of rated),
P_D	=	core thermal power at State Point D (% of rated),
W_C	=	core flow rate at State Point C (% of rated),
W_D	=	core flow rate at State Point D (% of rated),

The range of validity of the fit is: $31.2\% \leq \%\text{Flow} \leq 51.0\%$

2.5. Power/Flow Map

Power operation, with respect to Core Thermal Power/Total Core Flow combinations, is allowed within the 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 in terms of feedwater flow. This interlock ensures NPSH requirements for jet pumps and recirculation pumps 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.

- Buffer Region Boundary; The Buffer Region is determined by adjusting the endpoints of the Exclusion Region to meet a 0.65 decay ratio OR increasing the flow on the highest rod line by 5% and decreasing power on the natural circulation line by 5% if more limiting than the 0.65 decay ratio intercepts.

- Rated Power Line and MELLLA Boundary; These lines provide the upper power limit and operating domain assumed in plant safety 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 107% of rated core flow.

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 (64.80%CTP), core flow less than 26.35 M#/hr (54.9%) and maximum rod line less than 90% (References 3.2 and 3.3).

2.7. Rod Block Monitoring

The Rod Block Monitor (RBM) control rod block functions are no longer credited in the Rod Withdrawal Error (RWE) Analysis and as such, do not affect the MCPR Operating Limit. The RBM setpoints are based on providing operational flexibility in the MELLLA region (TS Bases 3.2). The rod block monitor (RBM) setpoint equation maximum value of N for single loop and dual loop operation are listed in Table 2.2-2.

Table 2.1-1

MAPLHGR Limits for GNF2 Fuel Types:

Average Planar Exposure (GWd/ST)	MAPLHGR (kW/ft)	
	Two Loop Operation	Single Loop Operation[1]
0	13.78	11.30
17.52	13.78	11.30
60.78	7.50	6.15
63.50	6.69	5.49

Table 2.1-2

MAPLHGR Limits for GE14 Fuel Types:

Average Planar Exposure (GWd/ST)	MAPLHGR (kW/ft)	
	Two Loop Operation	Single Loop Operation[1]
0	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.

[1] MAPLHGR for single loop operation is obtained by multiplying MAPLHGR for two loop operation by 0.82.

Table 2.2-1

Rated MCPR Operating Limits (OLMCPR)

Option/Fuel Type	Cycle Exposure Range	Two Loop Operation[2]	Single Loop Operation[1]
Option A/GE14	0 to 8,800 MWd/St	1.47	1.48
	Beyond 8,800 MWd/St	1.58	1.59
Option A/GNF2	0 to 8,800 MWd/St	1.51	1.52
	Beyond 8,800 MWd/St	1.54	1.55
Option B/GE14	0 to 8,800 MWd/St	1.40	1.41
	Beyond 8,800 MWd/St	1.41	1.42
Option B/GNF2	0 to 8,800 MWd/St	1.41	1.42
	Beyond 8,800 MWd/St	1.44	1.45

Source: References 3.6.

1 The MCPR operating limit is increased by 0.01 for single loop operation.
2 The two loop MCPR operating limits bound ICF operation throughout the cycle.

Table 2.2-2
RBM Setpoint[3]

Dual Loop Operation Maximum Value of "N" in RBM Setpoint Equation – 62.
Single Loop Operation Maximum Value of "N" in RBM Setpoint Equation – 68.

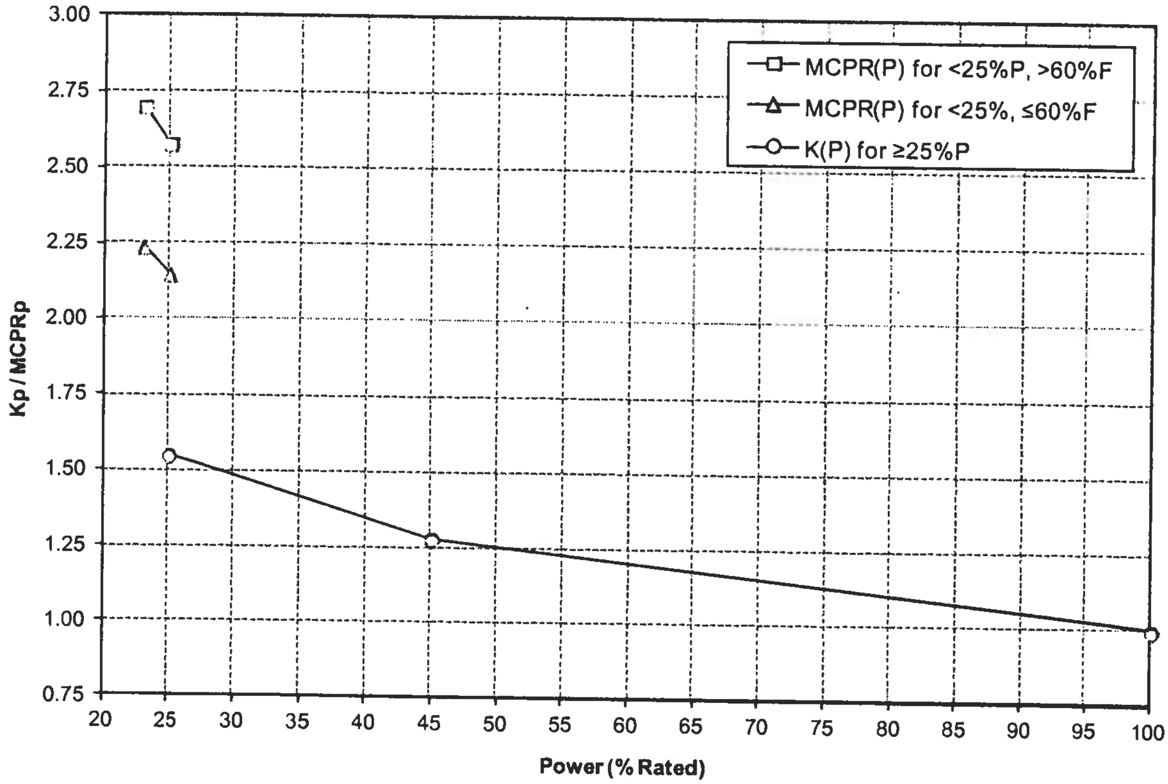
Source: Reference 3.8

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.

<u>Figure 2.2-1</u>

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



Operating Limit MCPR(P) = K(P) * Operating Limit MCPR(100)
For P < 23%, No Thermal Limits Required
P-Bypass = 25% Rated Power
MCPR(P) limits are based on a 1.09 SLMCPR

MCPR(P) for <25%P, >60%F

POWER	LIMIT
23.0	2.70
25.0	2.58

<u>EQUATIONS</u>

For 23% ≤ P < 25%: MCPR(P) = 2.58+ 6.00E-02(25.0 - P)

MCPR(P) for <25%P, ≤60%F

POWER	LIMIT
23.0	2.24
25.0	2.15

<u>EQUATIONS</u>

For 23% ≤ P < 25%: MCPR(P) = 2.15+ 4.50E-02(25.0 - P)

K(P) for ≥25%P

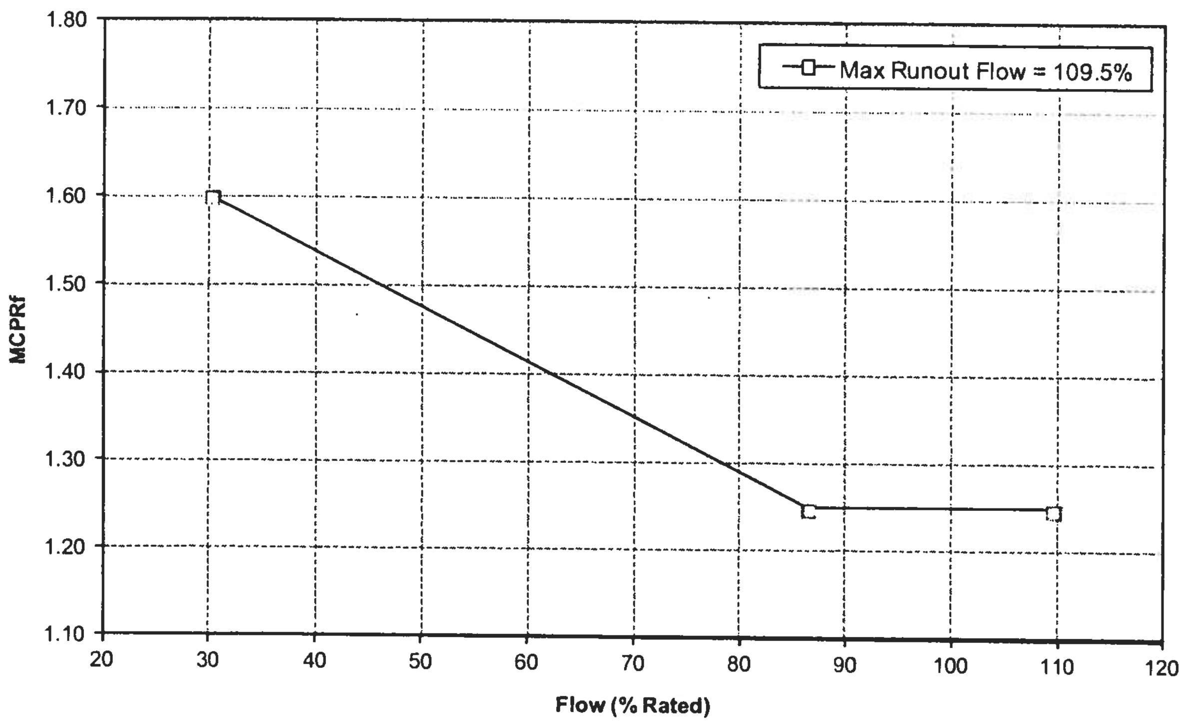
POWER	LIMIT
25.0	1.55
45.0	1.28
100.0	1.00

<u>EQUATIONS</u>

For 25% ≤ P < 45%: MCPR(P) = 1.28 + 1.35E-02(45.0 - P)
For 45% ≤ P < 100%: MCPR(P) = 1.00 + 5.09E-03(100.0 - P)

Figure 2.2-2

Flow Dependent MCPR Operating Limit MCPR (F)
(Technical Specification Reference 3.11.C)



MCPR(F) limits are based on a 1.09 SLMCPR

Max Runout Flow = 109.5%

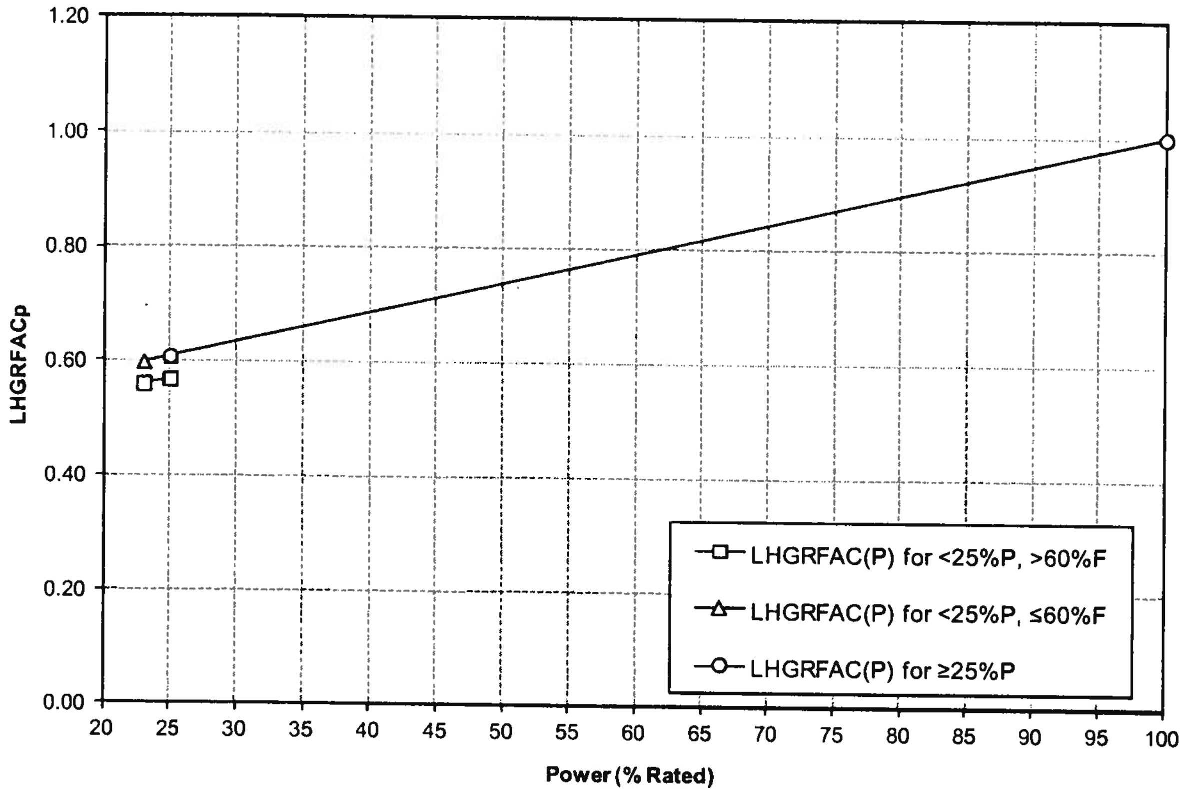
FLOW	LIMIT
30.0	1.60
86.3	1.25
109.5	1.25

EQUATIONS

For 30% ≤ F ≤ 109.5%: MCPR(F) = MAX(1.25, -0.622*F/100 + 1.7865

Figure 2.3-1

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



LHGR(P) = LHGRFAC(P) * LHGRstd
For P < 23%, No Thermal Limits Required
P-Bypass = 25% Rated Power

LHGRFAC(P) for <25%P, >60%F

POWER	LIMIT
23.0	0.560
25.0	0.568

EQUATIONS

For 23% ≤ P < 25%: LHGRFAC(P) = 0.568 + 4.00E-03(P - 25.0)

LHGRFAC(P) for <25%P, ≤60%F

POWER	LIMIT
23.0	0.598
25.0	0.608

EQUATIONS

For 23% ≤ P < 25%: LHGRFAC(P) = 0.608 + 5.00E-03(P - 25.0)

LHGRFAC(P) for ≥25%P

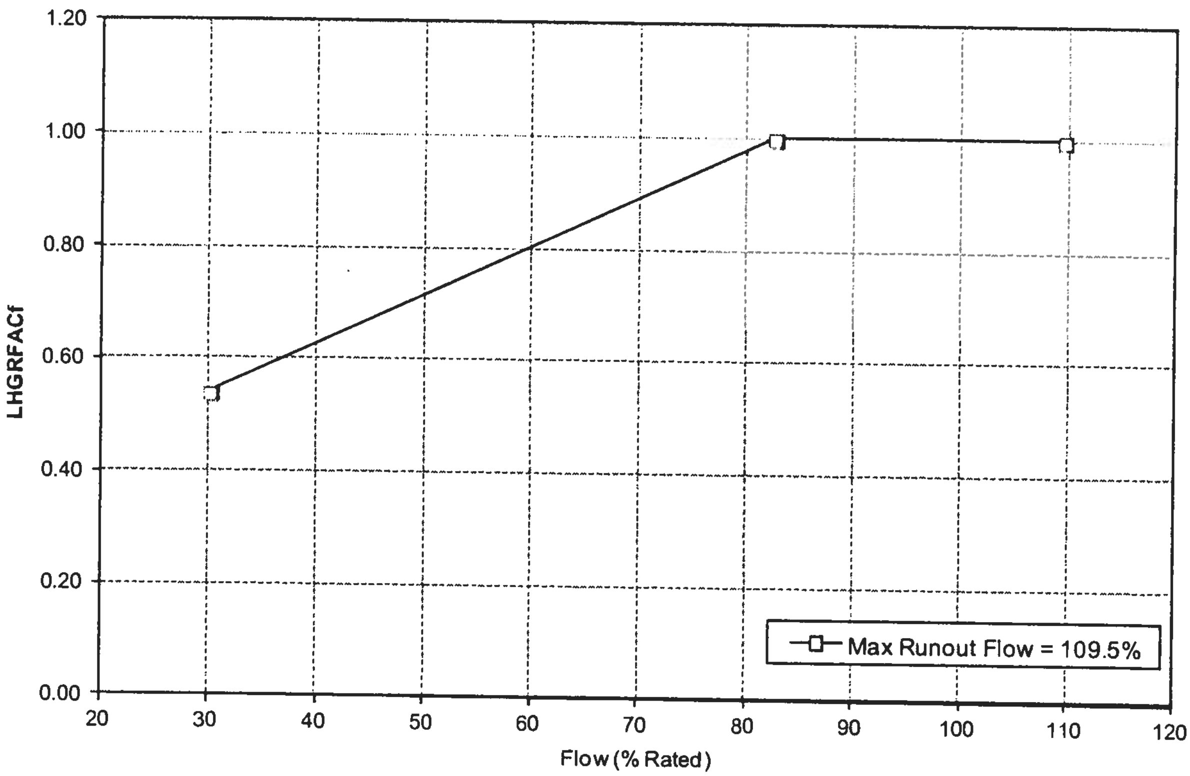
POWER	LIMIT
25.0	0.608
100.0	1.000

EQUATIONS

For 25% ≤ P < 100%: LHGRFAC(P) = 1.000 + 5.23E-03(P - 100.0)

Figure 2.3-2

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



LHGR(F) = LHGRFAC(F) * LHGRstd

Max Runout Flow = 109.5%

FLOW	LIMIT
30.0	0.54
82.6	1.00
109.5	1.00

EQUATIONS

For 30% ≤ F ≤ 109.5%: LHGRFAC(F) = MIN(1.00, [A(F)*F/100+B(F)])

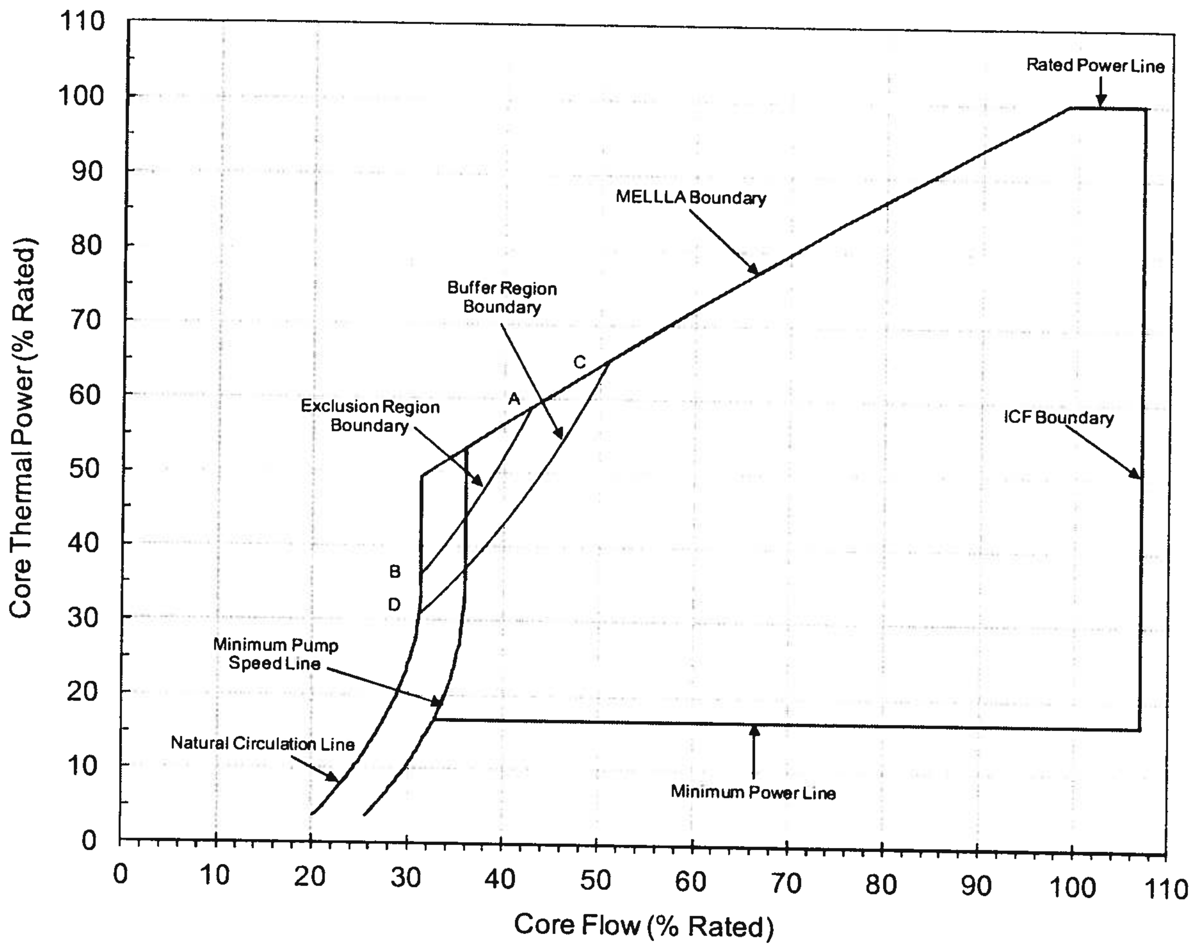
A(F) = 0.874

B(F) = 0.278

Figure 2.4-1

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

CYCLE 29 POWER/FLOW MAP



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