Vermont Yankee Nuclear Power Station
Cycle 20
Core Operating Limits Report
Revision 3

September 1999

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REVISION RECORD

Cycle	Revision	Date	Description
14	0	10/89	Initial printing. Reviewed by PORC and approved by management.
15	0	9/90	Cycle 15 revisions. Reviewed by PORC and approved by management.
15	1	11/91	Incorporate new MCPR limits to allow operation within the exposure window. Reviewed by PORC and approved by management.
16	0	3/92	Cycle 16 revisions. Reviewed by PORC and approved by management.
17	0	7/93	Cycle 17 revisions. Reviewed by PORC and approved by management.
18	0	4/95	Cycle 18 revisions. Reviewed by PORC and approved by management.
18	1	8/95	Incorporate new MAPLHGR limits to account for Loss of Stator Cooling Event. Reviewed by PORC and approved by management.
18	2	8/95	Incorporate the thermal-hydraulic stability exclusion region. Reviewed by PORC and approved by management.
18	3	11/95	Revise the thermal-hydraulic stability exclusion region to more accurately represent the exclusion region boundary equation. Revise the MCPR limits to allow SRV and SV setpoint tolerance relaxation. Reviewed by PORC and approved by management.
19	0	10/96	Cycle 19 revisions. Reviewed by PORC and approved by management.
20	0	5/98	Cycle 20 revisions. Reviewed by PORC and approved by management.
20	1	5/98	Revise the thermal-hydraulic stability exclusion region. Reviewed by PORC and approved by management.

Cycle	Revision	Date	Description
20	2	2/99	Revise LOSC transient analysis to eliminate MAPLHGR penalties required for 20 fuel assemblies.
20	3	9/99	Revise MCPR limits, K_f curves, and Power/Flow Map in support of Increased Core Flow. Add requirement for RBM rod block setpoint to be ≤ 108% power.

ABSTRACT

This report presents the cycle-specific operating limits for the operation of Cycle 20 of the Vermont Yankee Nuclear Power Station. The limits are the maximum average planar linear heat generation rate, maximum linear heat generation rate, minimum critical power ratio, and thermal-hydraulic stability exclusion region.

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1.0 INTRODUCTION

This report provides the cycle-specific limits for operation of the Vermont Yankee Nuclear Power Station in Cycle 20. It includes the limits for the maximum average planar linear heat generation rate, maximum 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.

This report has been prepared in accordance with the requirements of Technical Specification 6.7.A.4. The core operating limits have been developed using the NRC-approved methodologies listed in References 1 through 3. The methodologies are also listed in Technical Specification 6.7.A.4. The bases for these limits are in References 5 through 8.

2.0 CORE OPERATING LIMITS

The Cycle 20 operating limits have been defined using NRC-approved methodologies. Cycle 20 must be operated within the bounds of these limits and all others specified in the Technical Specifications.

2.1 Maximum Average Planar Linear Heat Generation Rate Limits

During steady-state power operation, the Maximum Average Planar Linear Heat Generation Rate (MAPLHGR) for each fuel type, as a function of the average planar exposure, shall not exceed the limiting values shown in Tables 2.1-1 through 2.1-5. Due to very conservative assumptions in the original Cycle 20 LOSC transient analysis, 20 BP8DWB354-12GZ fuel bundles were required to have a MAPLHGR penalty. The LOSC transient analysis has been re-performed, resulting in the elimination of the MAPLHGR penalty for these 20 bundles. All BP8DWB354-12GZ bundles will now have the same required MAPLHGR limits. 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 5). The source of these values is identified on each table. These tables only list the limits for fuel types in Cycle 20.

The MAPLHGR values are usually the most limiting composite of the fuel thermal-mechanical design analysis MAPLHGRs and the Loss-of-Coolant Accident (LOCA) MAPLHGRs. The fuel thermal-mechanical design analysis, using the methods in Reference 1, demonstrates that all fuel rods in a lattice, operating at the bounding power history, meet the fuel design limits specified in Reference 1. The Vermont Yankee LOCA analysis, performed in conformance with the requirements of 10CFR50.46 and Appendix K demonstrates that the LOCA analysis MAPLHGR values are bounded at all exposure points by the thermal-mechanical design analysis MAPLHGR values.

The MAPLHGR actually varies axially, depending upon the specific combination of enriched uranium and gadolinia that comprises a fuel bundle cross section at a particular axial node. Each particular combination of enriched uranium and gadolinia is called a lattice type. Each lattice type has a set of MAPLHGR values that vary with fuel burnup. The process computer will verify that these lattice MAPLHGR limits are not violated. Tables 2.1-1 through 2.1-5 provide a limiting composite of MAPLHGR values for each fuel type, which envelope the lattice MAPLHGR values employed by the process computer. When hand calculations are required, these MAPLHGR values are used for all lattices in the bundle.

2.2 Minimum Critical Power Ratio Limits

During steady-state power operation, the Minimum Critical Power Ratio (MCPR) shall be equal to, or greater than, the limits shown in Table 2.2-1. The non-ICF MCPR limits are valid for rated power operation up to a cycle exposure of 10700 MWd/St, which is the licensed end of cycle exposure. The ICF MCPR limits are valid for rated

power operation up to a cycle exposure of 11000 MWd/St, which is the licensed extended end of cycle exposure. Either of these exposure values may be exceeded, provided the plant is coasting down. 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 (Reference 7).

For core flows other than the rated condition, the MCPR limit shall be the appropriate value from Table 2.2-1 multiplied by K_f, where K_f is given in Figure 2.2-1 as a function of the Recirc MG Set Stop setting. Interpolation between K_f curves is allowable, provided the curve used is conservative to the Recirc MG Set Stop setting.

Also listed is the maximum RBM rod block setpoint to which the designated MCPR limits apply. This value determines the RBM rod block clamp setpoint.

These limits are only valid for the fuel types in Cycle 20.

2.3 Maximum Linear Heat Generation Rate Limits

During steady-state power operation, the Linear Heat Generation Rate (LHGR) of any rod in any fuel bundle at any axial location shall not exceed the maximum allowable LHGR limits in Table 2.3-1. This table only lists the limits for fuel types in Cycle 20.

2.4 Thermal-Hydraulic Stability Exclusion Region

Normal plant operation is not allowed inside the bounds of the exclusion region defined in Figure 2.4-1, Reference 7. These power and flow limits are applicable for Cycle 20. 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.

The coordinates of the Exclusion Region are as follows:

Point	Power (%)	Flow (%)
A	74.9	49.8
B	30.7	25.4

The equation for the boundary is as follows:

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

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_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: $25.4\% \leq \%\text{Flow} \leq 49.8\%$

The coordinates of the Buffer Region are as follows:

Point	Power (%)	Flow (%)
C	78.2	54.8
D	25.7	24.3

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

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

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_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: 24.3% $\leq$%Flow $\leq$54.8%.

Table 2.1-1

MAPLHGR Versus Average Planar Exposure for BP8DWB335-10GZ Fuel Bundle No. 2017

Plant: Vermont Yankee

Fuel Type: P8DWB335-10GZ

Average Planar Exposure (MWd/ST)	MAPLHGR (kW/ft)	
	Two Loop Operation	Single Loop Operation[1]
0.00	11.29	9.25
200.00	11.34	9.29
1,000.00	11.48	9.41
2,000.00	11.69	9.58
3,000.00	11.92	9.77
4,000.00	12.17	9.97
5,000.00	12.43	10.19
6,000.00	12.68	10.39
7,000.00	12.87	10.55
8,000.00	13.06	10.70
9,000.00	13.24	10.85
10,000.00	13.35	10.94
12,500.00	13.20	10.82
15,000.00	13.01	10.66
20,000.00	12.27	10.06
25,000.00	11.43	9.37
35,000.00	9.88	8.10
45,000.00	8.38	6.87
50,590.00	5.65	4.63

Source: NEDC-32814P, Report, Vermont Yankee Nuclear Power Station SAFER/GESTR-LOCA, Loss-of-Coolant Analysis, Reference 5. 24A5416AA, Revision 0, GE Report, Lattice Dependent MAPLHGR Report for Vermont Yankee Nuclear Power Station Reload 19 Cycle 20, Reference 8.

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 2.1-2

MAPLHGR Versus Average Planar Exposure for BP8DWB335-11GZ Fuel Bundle No. 2018

Plant: Vermont Yankee

Fuel Type: P8DWB335-11GZ

Average Planar Exposure (MWd/ST)	MAPLHGR (kW/ft)	
	Two Loop Operation	Single Loop Operation[1]
0.00	11.28	9.24
200.00	11.33	9.29
1,000.00	11.43	9.37
2,000.00	11.60	9.51
3,000.00	11.80	9.67
4,000.00	12.04	9.87
5,000.00	12.30	10.08
6,000.00	12.53	10.27
7,000.00	12.73	10.43
8,000.00	12.94	10.61
9,000.00	13.13	10.76
10,000.00	13.29	10.89
12,500.00	13.20	10.82
15,000.00	12.99	10.65
20,000.00	12.27	10.06
25,000.00	11.43	9.37
35,000.00	9.88	8.10
45,000.00	8.38	6.87
50,590.00	5.65	4.63

Source: NEDC-32814P, Report, Vermont Yankee Nuclear Power Station SAFER/GESTR-LOCA, Loss-of-Coolant Analysis, Reference 5. 24A5416AA, Revision 0, GE Report, Lattice Dependent MAPLHGR Report for Vermont Yankee Nuclear Power Station Reload 19 Cycle 20, Reference 8.

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 2.1-3

MAPLHGR Versus Average Planar Exposure for BP8DWB354-12GZ Fuel Bundle No. 2153

Plant: Vermont Yankee

Fuel Type: P8DWB354-12GZ

Average Planar Exposure (MWd/ST)	MAPLHGR (kW/ft)	
	Two Loop Operation	Single Loop Operation[1]
0.00	10.96	8.98
200.00	11.04	9.05
1,000.00	11.18	9.16
2,000.00	11.40	9.34
3,000.00	11.63	9.53
4,000.00	11.81	9.68
5,000.00	12.01	9.84
6,000.00	12.14	9.95
7,000.00	12.26	10.05
8,000.00	12.37	10.14
9,000.00	12.46	10.21
10,000.00	12.52	10.26
12,500.00	12.40	10.16
15,000.00	12.10	9.92
20,000.00	11.40	9.34
25,000.00	10.72	8.79
35,000.00	9.44	7.74
45,000.00	7.24	5.93
48,200.00	5.67	4.65

Source: NEDC-32814P, Report, Vermont Yankee Nuclear Power Station SAFER/GESTR-LOCA, Loss-of-Coolant Analysis, Reference 5. 24A5416AA, Revision 0, GE Report, Lattice Dependent MAPLHGR Report for Vermont Yankee Nuclear Power Station Reload 19 Cycle 20, Reference 8.

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 2.1-4

MAPLHGR Versus Average Planar Exposure for P9HTB380-12GZ Fuel
Bundle No. 2278

Plant: Vermont Yankee

Fuel Type: P9HTB380-12GZ

Average Planar Exposure (MWd/ST)	MAPLHGR (kW/ft)	
	Two Loop Operation	Single Loop Operation[1]
0.00	10.64	8.72
200.00	10.71	8.78
1.000.00	10.85	8.89
2.000.00	11.04	9.05
3.000.00	11.23	9.20
4.000.00	11.43	9.37
5.000.00	11.64	9.54
6.000.00	11.82	9.69
7.000.00	11.96	9.80
8.000.00	12.12	9.93
9.000.00	12.27	10.06
10.000.00	12.44	10.20
12.500.00	12.57	10.30
15.000.00	12.24	10.03
17.500.00	11.90	9.75
20.000.00	11.54	9.46
25.000.00	10.82	8.87
30.000.00	10.12	8.29
35.000.00	9.43	7.73
40.000.00	8.76	7.18
45.000.00	8.10	6.64
50.000.00	7.44	6.10
55.000.00	6.77	5.55
57.480.00	6.43	5.27
57.580.00	6.42	5.26

Source: NEDC-32814P, Report, Vermont Yankee Nuclear Power Station SAFER/GESTR-LOCA, Loss-of-Coolant Analysis, Reference 5. 24A5416AA, Revision 0, GE Report, Lattice Dependent MAPLHGR Report for Vermont Yankee Nuclear Power Station Reload 19 Cycle 20, Reference 8.

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 2.1-5

MAPLHGR Versus Average Planar Exposure for P9HTB379-13GZ Fuel
Bundle No. 2279

Plant: Vermont Yankee

Fuel Type: P9HTB379-13GZ

Average Planar Exposure (MWd/ST)	MAPLHGR (kW/ft)	
	Two Loop Operation	Single Loop Operation[1]
0.00	10.64	8.72
200.00	10.69	8.76
1.000.00	10.81	8.86
2.000.00	10.99	9.01
3.000.00	11.18	9.16
4.000.00	11.36	9.31
5.000.00	11.49	9.42
6.000.00	11.63	9.53
7.000.00	11.78	9.65
8.000.00	11.92	9.77
9.000.00	12.07	9.89
10.000.00	12.22	10.02
12.500.00	12.33	10.11
15.000.00	12.23	10.02
17.500.00	11.90	9.75
20.000.00	11.54	9.46
25.000.00	10.82	8.87
30.000.00	10.11	8.29
35.000.00	9.42	7.72
40.000.00	8.75	7.17
45.000.00	8.09	6.63
50.000.00	7.43	6.09
55.000.00	6.76	5.54
57.500.00	6.42	5.26
57.560.00	6.40	5.24

Source: NEDC-32814P, Report, Vermont Yankee Nuclear Power Station SAFER/GESTR-LOCA, Loss-of-Coolant Analysis, Reference 5. 24A5416AA, Revision 0, GE Report, Lattice Dependent MAPLHGR Report for Vermont Yankee Nuclear Power Station Reload 19 Cycle 20, Reference 8.

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

Vermont Yankee Nuclear Power Station
Cycle 20 MCPR Operating Limits

Value of "N" in RBM Equation (A)[1]	Average Control Rod Scram Time	Cycle Exposure Range	Two Loop Operation	Single Loop Operation[2]
42%	Equal to or better than L.C.O. 3.3.C.1.1	0.0 to 8175 MWd/St	1.33	1.35
		8175 to 9175 MWd/St	1.34	1.36
		9175 to 10700 MWd/St[3]	1.37	1.39
		0.0 to 11000 MWd/St[3,4]	1.40	1.42
	Equal to or better than L.C.O. 3.3.C.1.2	0.0 to 8175 MWd/St	1.37	1.39
		8175 to 9175 MWd/St	1.38	1.40
		9175 to 10700 MWd/St[3]	1.47	1.49
		0.0 to 11000 MWd/St[3,4]	1.50	1.52

Maximum Allowable RBM Rod Block setpoint – 108% power.

Source: Report, Cycle Management Report for Vermont Yankee Nuclear Power Station Cycle 20, J11-03297 CMR, Rev. 0, April 1998, Reference 6. Report, General Electric Nuclear Energy, Supplemental Reload Licensing Report for Vermont Yankee Nuclear Power Station Reload 19/Cycle 20, 24A5416, Rev. 3, January 1999, Reference 7.

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

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

2 The MCPR operating limits should be increased by 0.02 for the single loop operation.

3 Exposure value is the limit for rated power operation. Operation beyond this exposure is allowable, provided plant is coasting down.

4 ICF MCPR Operating Limits listed are for operation at ICF conditions at any time during the cycle.

Table 2.3-1

Maximum Allowable Linear Heat Generation Rate Limits

Fuel Type	Maximum Allowable Linear Heat Generation Rate (kW/ft)
BP8DWB335-10GZ	14.4
BP8DWB335-11GZ	14.4
BP8DWB354-12GZ	14.4
P9HTB380-12GZ	14.4
P9HTB379-13GZ	14.4

Source: NEDE-24011-P-A, Reference 1.

Technical Specification References: 2.1.A.1a, 2.1.B.1, and 3.11.B.

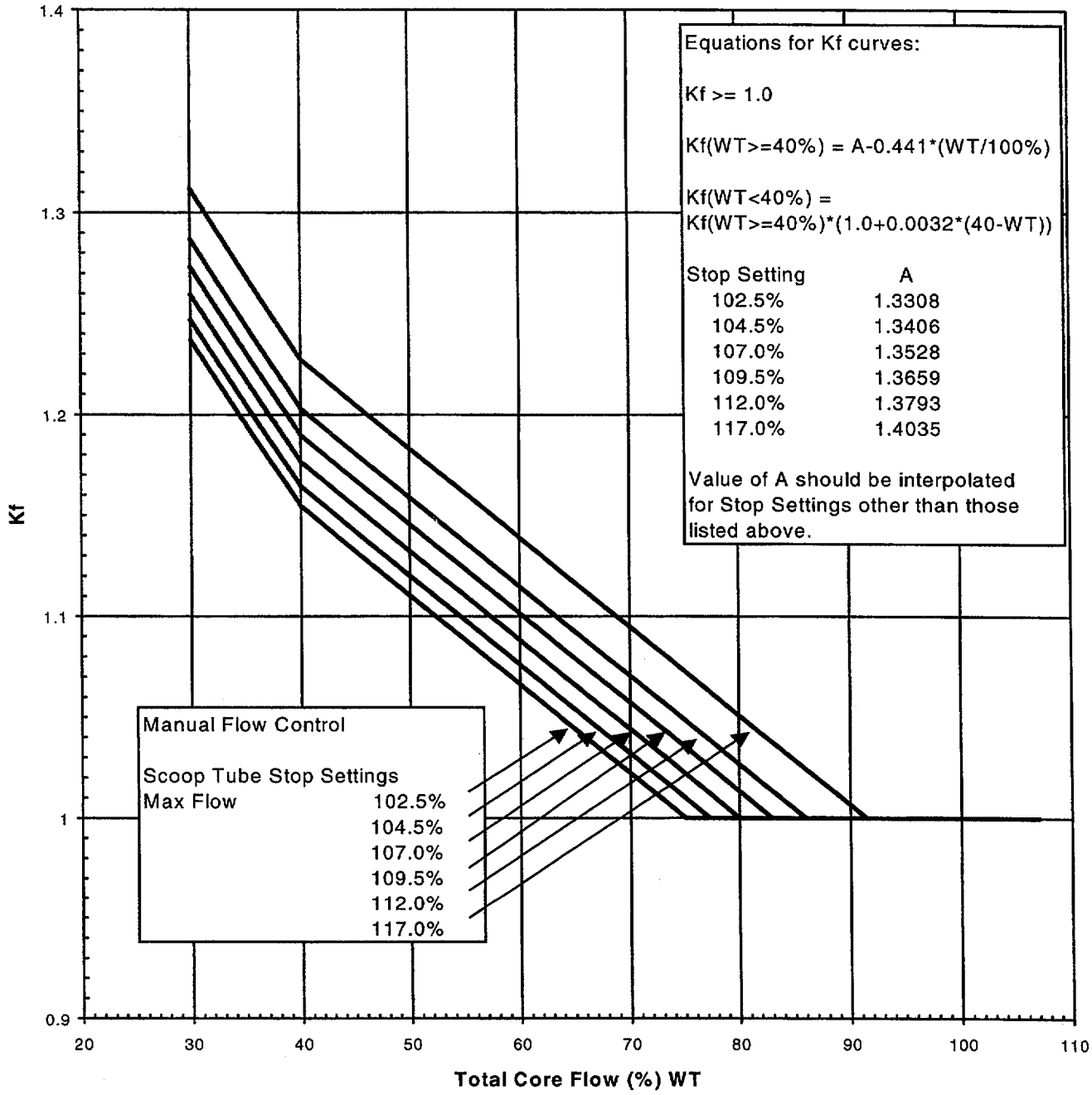

Figure 2.2-1

K_f vs. Total Core Flow
(Technical Specification Reference 3.11.C)

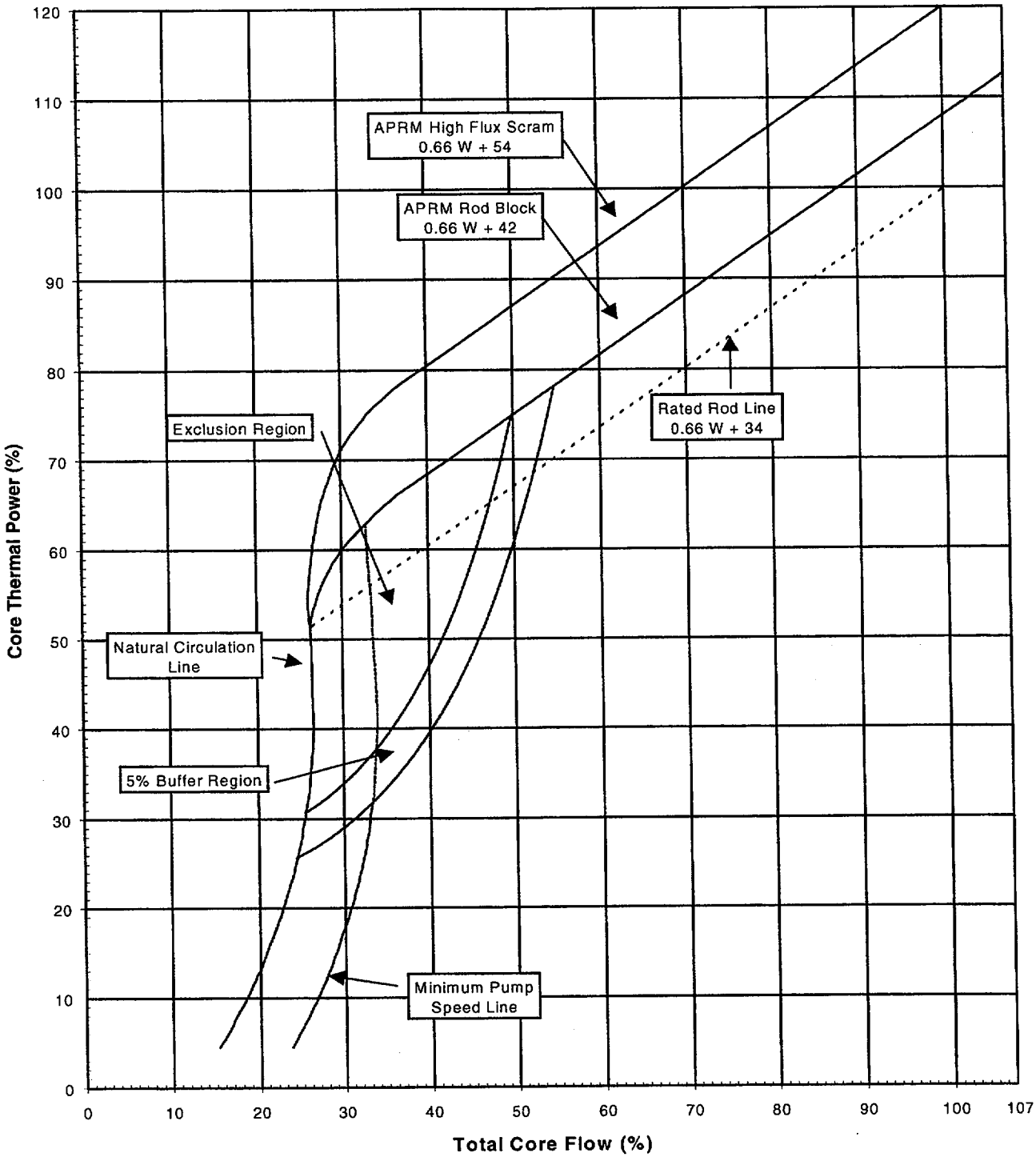

Figure 2.4-1

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

3.0 REFERENCES

1. Report, General Electric Standard Application for Reactor Fuel (GESTARII), NEDE-24011-P-A-13, GE Company Proprietary, August 1996, as amended.

2. Report, General Electric Nuclear Energy, BWR Owners' Group Long-Term Stability Solutions Licensing Methodology, NEDO-31960, June 1991.

3. Report, General Electric Nuclear Energy, BWR Owners' Group Long-Term Stability Solutions Licensing Methodology, NEDO-31960, Supplement 1, March 1992.

4. Letter, USNRC to VYNPC, SER, August 9, 1995.

5. Report, Vermont Yankee Nuclear Power Station SAFER/GESTR-LOCA Loss-of-Coolant Analysis, NEDC-32814P, March 1998.

6. Report, Cycle Management Report for Vermont Yankee Nuclear Power Station Cycle 20, J11-03297 CMR, Rev. 0, April 1998.

7. Report, General Electric Nuclear Energy, Supplemental Reload Licensing Report for Vermont Yankee Nuclear Power Station Reload 19/Cycle 20, 24A5416, Rev. 3, January 1999.

8. Report, Lattice Dependent MAPLHGR Report for Vermont Yankee Nuclear Power Station Reload 19, Cycle 20, 24A5416AA, Rev. 0, March 1998.

9.* Report, BWR Owners' Group Long-Term Stability Solutions Licensing Methodology," NEDO-31960-A, November 1995.

10.* Report, BWR Owners' Group Long-Term Stability Solutions Licensing Methodology," NEDO-31960-A, Supplement 1, November 1995.

11. Report, Vermont Yankee Nuclear Power Station Increased Core Flow Analysis, NEDC-32791P, February 1999.

*References 9 and 10 are the generically approved documents for References 2 and 3, including the SER from Reference 4.