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PILGRIM NUCLEAR POWER STATION UNIT 1

LICENSE AMENDMENT FOR SINGLE-LOOP OPERATION

BOILING WATER REACTOR PROJECTS DEPARTMENT • GENERAL ELECTRIC COMPANY
SAN JOSE, CALIFORNIA 95125
GENERAL ELECTRIC

TABLE OF CONTENTS

Section		Page
1.	Introduction	1-1
2.	Loss-of-Coolant Accident	2-1
3.	One-Pump Seizure Accident	3-1
4.	Abnormal Operational Transient	4-1
5.	Stability Analysis	5-1
6.	References	6-1

LIST OF ILLUSTRATIONS

Figure	Title	Page
1	MAPLHGR Reduction Factor Versus Reflood Time	2-8
2A.1	Peak Cladding Temperature and Maximum Local Metal-Water Reaction versus Planar Average Exposure, Pilgrim NPS Unit 1, Initial Core - No Curtains, Single-Loop Operation, Plugged Bypass Holes, Recirculation Equalizer Valve Closed	2-15
2B.1	Maximum Average Planar Linear Heat Generation Rate (MAPLHGR) versus Planar Average Exposure, Pilgrim NPS Unit 1, Initial Core - No Curtains, Single-Loop Operation, Plugged Bypass Holes, Recirculation Equalizer Valve Closed	2-15
2A.2	Peak Cladding Temperature and Maximum Local Metal-Water Reaction versus Planar Average Exposure, Pilgrim NPS Unit 1, Initial Core - 1 Weak Curtain, Single-Loop Operation, Plugged Bypass Holes, Recirculation Equalizer Valve Closed	2-16
2B.2	Maximum Average Planar Linear Heat Generation Rate (MAPLHGR) versus Planar Average Exposure, Pilgrim NPS Unit 1, Initial Core - 1 Weak Curtain, Single-Loop Operation, Plugged Bypass Holes, Recirculation Equalizer Valve Closed	2-16
2A.3	Peak Cladding Temperature and Maximum Local Metal-Water Reaction versus Planar Average Exposure, Pilgrim NPS Unit 1, Initial Core - 2 Weak Curtains, Single-Loop Operation, Plugged Bypass Holes, Recirculation Equalizer Valve Closed	2-17
2B.3	Maximum Average Planar Linear Heat Generation Rate (MAPLHGR) versus Planar Average Exposure, Pilgrim NPS Unit 1, Initial Core - 2 Weak Curtains, Single-Loop Operation, Plugged Bypass Holes, Recirculation Equalizer Valve Closed	2-17
2A.4	Peak Cladding Temperature and Maximum Local Metal-Water Reaction versus Planar Average Exposure, Pilgrim NPS Unit 1, Initial Core - 1 Weak Curtain, 1 Strong Curtain, Single-Loop Operation, Plugged Bypass Holes, Recirculation Equalizer Valve Closed	2-18
2B.4	Maximum Average Planar Linear Heat Generation Rate (MAPLHGR) versus Planar Average Exposure, Pilgrim NPS Unit 1, Initial Core - 1 Weak Curtain, 1 Strong Curtain, Single-Loop Operation, Plugged Bypass Holes, Recirculation Equalizer Valve Closed	2-18
2A.5	Peak Cladding Temperature and Maximum Local Metal-Water Reaction versus Planar Average Exposure, Pilgrim NPS Unit 1, Initial Core - 1 Strong Curtain, Single-Loop Operation, Plugged Bypass Holes, Recirculation Equalizer Valve Closed	2-19
2B.5	Maximum Average Planar Linear Heat Generation Rate (MAPLHGR) versus Planar Average Exposure, Pilgrim NPS Unit 1, Initial Core - 1 Strong Curtain, Single-Loop Operation, Plugged Bypass Holes, Recirculation Equalizer Valve Closed	2-19

LIST OF ILLUSTRATIONS (Continued)

Figure	Title	Page
2A.6	Peak Cladding Temperature and Maximum Local Metal-Water Reaction versus Planar Average Exposure, Pilgrim NPS Unit 1, Initial Core - 2 Strong Curtains, Single-Loop Operation, Plugged Bypass Holes, Recirculation Equalizer Valve Closed	2-20
2B.6	Maximum Average Planar Linear Heat Generation Rate (MAPLHGR) versus Planar Average Exposure, Pilgrim NPS Unit 1, Initial Core - 2 Strong Curtains, Single-Loop Operation, Plugged Bypass Holes, Recirculation Equalizer Valve Closed	2-20
2A.7	Peak Cladding Temperature and Maximum Local Metal-Water Reaction versus Planar Average Exposure, Pilgrim NPS Unit 1, 8D262 Fuel, Single-Loop Operation, Plugged Bypass Holes, Recirculation Equalizer Valve Closed	2-21
2B.7	Maximum Average Planar Linear Heat Generation Rate (MAPLHGR) versus Planar Average Exposure, Pilgrim NPS Unit 1, 8D262 Fuel, Single-Loop Operation, Plugged Bypass Holes, Recirculation Equalizer Valve Closed	2-21
3	Main Turbine Trip with Bypass Manual Flow Control	4-2
4	Core Flow Versus Drive Flow for One-and-Two-Pump Operation	4-5

LIST OF TABLES

		Page
2-1	Results of Blowdown and Reflooding Calculations for a BWR/3-BWR/4 with an Early Reflooding Time	2-4
2-2	Results of Blowdown and Reflooding Calculations for a BWR/3-BWR/4 with a Late Reflooding Time	2-5
2-3	Comparison of One Pump and Two Pump Calculated Peak Cladding Temperatures for Large Breaks for the BWR/3-BWR/4 with the Earliest Reflooding Time	2-11

1. INTRODUCTION

Single-loop operation at reduced power is highly desirable in the event a recirculation pump or other component maintenance renders one loop inoperative. To justify single-loop operation, accidents and abnormal operational transients associated with power operations[1,2] were reviewed for one-pump operation.

Evaluations of significant events are presented in Sections 2 through 5. The reactor is assumed to be operating at some reduced flow and power on or below the rated flow control line except in the loss-of-coolant accident (LOCA) blowdown calculations in which the reactor is assumed to be operating at 102% rated power with corresponding core flow, steam flow, etc. These evaluations are valid only when the recirculation equalizer valve is closed.

These analyses have been performed on a generic basis. Conservative assumptions have been employed in the analysis to ensure the generic application of the results. Special application of the generic analysis of LOCA to Pilgrim is discussed in Subsection 2.3.

2. LOSS-OF-COOLANT ACCIDENT

2.1 SUMMARY

This section presents a conservative, generic analysis whereby existing MAPLHGR (Maximum Average Planar Linear Heat Generation Rate) curves corresponding to normal two-pump operation are modified to apply for the special case when only one recirculation pump is operating. This generic analysis assumes that the equalizer valve between the two recirculation loops remains closed. The results are applicable to all BWR/3's and BWR/4's including the LPCI-modified plants. All analysis is entirely in conformance with 10CFR50.46 Appendix K. Conservative assumptions have been employed in the analysis for the purpose of applying the results on a generic basis. The significant results of the analysis are:

1. Derivation of a MAPLHGR reduction factor, which is a function of the reflooding time for the Design Basis Accident. This factor is applied to existing MAPLHGR curves for two-pump operation to obtain conservative MAPLHGR values for one-pump operation.

2. Confirmation that the Design Basis Accident (DBA) which limits the two-pump MAPLHGR remains the limiting loss-of-coolant accident (LOCA) for evaluation of the one pump MAPLHGR, i.e., the break spectrum peak cladding temperature (PCT) decreases with break area for breaks smaller than the DBA.

2.2 ANALYSIS

If a pipe break occurs in one of the two operating recirculation loops, the pump in the unbroken loop is immediately tripped and begins to coastdown. The decaying core flow due to the pump coastdown results in very effective heat transfer (nucleate boiling) during the initial phase of the blowdown. Typically, nucleate boiling will be sustained during the first five to nine seconds after the accident. This is discussed in detail in Reference 3.

If only one recirculation pump is operating, and the break occurs in the operating loop, coastdown flow relies only on natural circulation because the vessel is blowing down to the reactor containment through both sections of the broken loop. The core flow decreases more rapidly than in the two-pump case, and the departure from nucleate boiling occurs within one or two seconds after the postulated accident, resulting in more severe cladding heatup for the one-pump operating case.

The following discussion describes a conservative generic analysis of the LOCA with one-pump operation.

2.2.1 Generic Approach

To minimize and simplify the calculational effort for one-pump MAPLHGR's, the following generic approach was taken. The effect of losing recirculation pump coastdown flow on the vessel blowdown and reflooding phenomena was investigated for two plants which are typical of BWR/3's and BWR/4's - one with an early reflooding time and one with a late reflooding time. Of particular interest are the changes in hot node uncovery and reflooding times, and the time at which core spray heat transfer is initiated. The results of this evaluation and a comparison to the two-pump operation base case are presented in Subsection 2.2.2. This comparison provides the basis for the generic quantification of the changes in these LOCA parameters for one-pump operation.

The generic approach is extended to the cladding heatup analysis to develop a correction factor as a function of reflooding time which is applied to the two-pump MAPLHGR's to obtain conservative MAPLHGR's for one-pump operation. The basic conservative assumption in the evaluation of MAPLHGR's for one-pump operation is that the transition from nucleate to film boiling occurs almost instantaneously (within 0.1 sec) after the LOCA due to the loss of recirculation pump coastdown flow. The evaluation of the correction factor along with the generic curves for suction and discharge breaks for BWR/3's and BWR/4's are presented in Subsections 2.2.3 and 2.2.4.

2.2.2 Vessel Blowdown and Reflooding Calculations

Blowdown and reflooding calculations for the one-pump operation case are performed for an early reflooding and a late reflooding BWR. The purpose is to determine the changes in the significant LOCA heatup analysis parameters due to one-pump operation.

The analysis was conducted with the following assumptions:

1. Standard Emergency Core Cooling System (ECCS) computer codes are used for the calculation.

2. The vessel blowdown calculation assumes no coastdown recirculation flow.

3. The reactor is assumed to be operating at 102% rated power with corresponding core flow, steam flow, pressure, etc. This assumption is conservative for operation at lower power (as expected in one-loop operation) in that calculations with the reactor operating at a reduced power level for one-pump operation show later core uncovery and earlier core reflooding - both of which result in less severe cladding heatup.

Table 2-1 presents a comparison of the major results of the blowdown and reflooding calculations for two-pump and one-pump operation for a BWR/3-BWR/4 with an early reflooding time. Results are included for the DBA, 80% DBA, 60% DBA, and 1 ft^2 breaks. Table 2-1 shows there are no major differences in the parameters for two-pump versus one-pump operation. The hot node uncovers (TUNC) slightly earlier (less than 1.0 sec) and refloods (TFLOOD) slightly later (less than 1.0 sec) for the one-pump case due to loss of recirculation pump coastdown flow. The time at which core spray heat transfer (TSPRAY) is assumed is also slightly different due to the different vessel depressurization rates for the two cases. The insignificant changes in these parameters for the DBA result in less than a 1% change in MAPLHGR.

Table 2-2 presents a similar comparison for the DBA of a BWR/3-BWR/4 with a late reflooding time. From these results it is seen that TUNC and TSPRAY remain unchanged, and that TFLOOD increases by only 2 seconds in going from two-pump to

Table 2-1

RESULTS OF BLOWDOWN AND REFLOODING CALCULATIONS FOR A BWR/3-BWR/4 WITH AN EARLY REFLOODING TIME

BREAK	PARAMETER (sec)	TWO-PUMP OPERATION	ONE-PUMP OPERATION
DBA	TUNC[a]	25.4	25.3
	TSPRAY[b]	33.5	33.9
	TFLOOD[c]	106.3	107.0
80% DBA	TUNC	28.1	27.9
	TSPRAY	39.6	39.9
	TFLOOD	103.6	103.9
60% DBA	TUNC	33.0	32.1
	TSPRAY	51.7	51.6
	TFLOOD	105.4	106.4
1.0 ft^2	TUNC	84.9	84.6
	TSPRAY	94.4	94.0
	TFLOOD	154.7	154.2

[a] TUNC = Hot node uncovery time (sec)

[b] TSPRAY = Time at which credit is assumed for core spray heat transfer (sec)

[c] TFLOOD = Reflooding time for hot node (sec)

one-pump operation. The effect of the 2-sec increase in reflooding time is to decrease the MAPLHGR by less than one-half percent.

Table 2-2

RESULTS OF BLOWDOWN AND REFLOODING CALCULATIONS FOR A BWR/3-BWR/4 WITH A LATE REFLOODING TIME

BREAK	PARAMETER (sec)	TWO-PUMP OPERATION	ONE-PUMP OPERATION
	TUNC	21.7	21.7
DBA	TSPRAY	26.1	26.1
	TFLOOD	245.6	247.6

From the comparison in Tables 2-1 and 2-2 it is seen that the changes in blowdown and reflooding calculations in going from two-pump to one-pump operation are small, and therefore, result in insignificant changes in MAPLHGR (always less than 1%). These changes are compensated for by the conservatisms in the heatup analysis as discussed in Subsections 2.2.3 and 2.2.4. Since these comparison calculations are made for typical BWR/3's and BWR/4's, no significant change in these parameters will occur in going from two-pump to one-pump operation for Pilgrim. Therefore, the values of TUNC, TSPRAY, and TFLOOD for two-pump operation will be used in all heatup calculations for one-pump operation.

2.2.3 Core Heatup and MAPLHGR Calculation

The parameters which most affect the MAPLHGR reduction for one-pump operation for BWR/3's and BWR/4's are the reflooding time and the time to the onset of boiling transition. In general, for plants with earlier reflooding times, the peak cladding temperature (PCT) is increasing at a higher rate immediately prior to reflooding. This is because the PCT for these plants is more sensitive to the amount of stored energy in the fuel remaining after the transition from nucleate to film boiling. In the heatup analysis for determining one-pump operation MAPLHGR's, it is assumed that boiling transition occurs at 0.1 sec after the accident. Ellion pool boiling heat transfer (Reference 3) is assumed thereafter until core uncovery. This conservative assumption maximizes the amount of remaining stored energy after boiling transition. Therefore, the MAPLHGR reduction, i.e., the reduction in maximum average planar power to ensure conformance with

10CFR50.46, from the two-pump case will be more severe for plants with earlier reflooding times.

The MAPLHGR reduction is calculated for both suction and discharge breaks (for plants with the LPCI modification) because the time to boiling transition is significantly longer (by at least 2 seconds) for the discharge break. Thus, the discharge break MAPLHGR is more severely reduced for one-pump operation.

Since the MAPLHGR reduction is sensitive to reflooding time, the heatup analysis to determine one pump MAPLHGR's is performed for selected BWR/3's and BWR/4's with reflooding times that vary at equal intervals from approximately 100 sec to 350 sec for the suction break, and from approximately 125 sec to 300 sec for the discharge break. Within a given interval of reflooding time the plant with the longest time to boiling transition was selected for the MAPLHGR reduction calculation. This choice was made because stored energy removal is higher for longer boiling transition times, and therefore, the MAPLHGR reduction from the two-pump case is most severe for plants with the longest times to boiling transition. Therefore, applying the MAPLHGR reduction generically to plants with comparable reflooding times, but shorter times to boiling transition, results in conservatively low MAPLHGR values.

Core heatup calculations for one-pump operation are performed with the following assumptions:

1. The standard ECCS heatup computer code is used.

2. In the heatup calculations, 102% of bundle power is assumed in conformance with 10CFR50.46 Appendix K.

3. The values of TUNC, TSPRAY, and TFLOOD used for the one-pump operation calculation remain unchanged from those used for the two-pump operation calculations The justification for this assumption is given in Subsection 2.2.2.

4. The heatup calculations are performed for 7x7 fuel rather than 8x8 fuel because the 7x7 heatup is more sensitive to the amount of stored energy remaining after nucleate boiling. The MAPLHGR reduction is more severe for 7x7 fuel; therefore, the 7x7 results can be applied to determine conservatively low one-pump MAPLHGR's for 8x8 fuel.

5. Departure from nucleate boiling is conservatively assumed at 0.1 second after the accident (at least one-to-two seconds of nucleate boiling is expected, even if there is no recirculation pump coastdown) after which the Ellion pool boiling correlation, which has been approved for use during low flow periods during the blowdown is assumed until hot node uncovery. No credit is taken for the improved heat transfer which will result from lower plenum flashing.

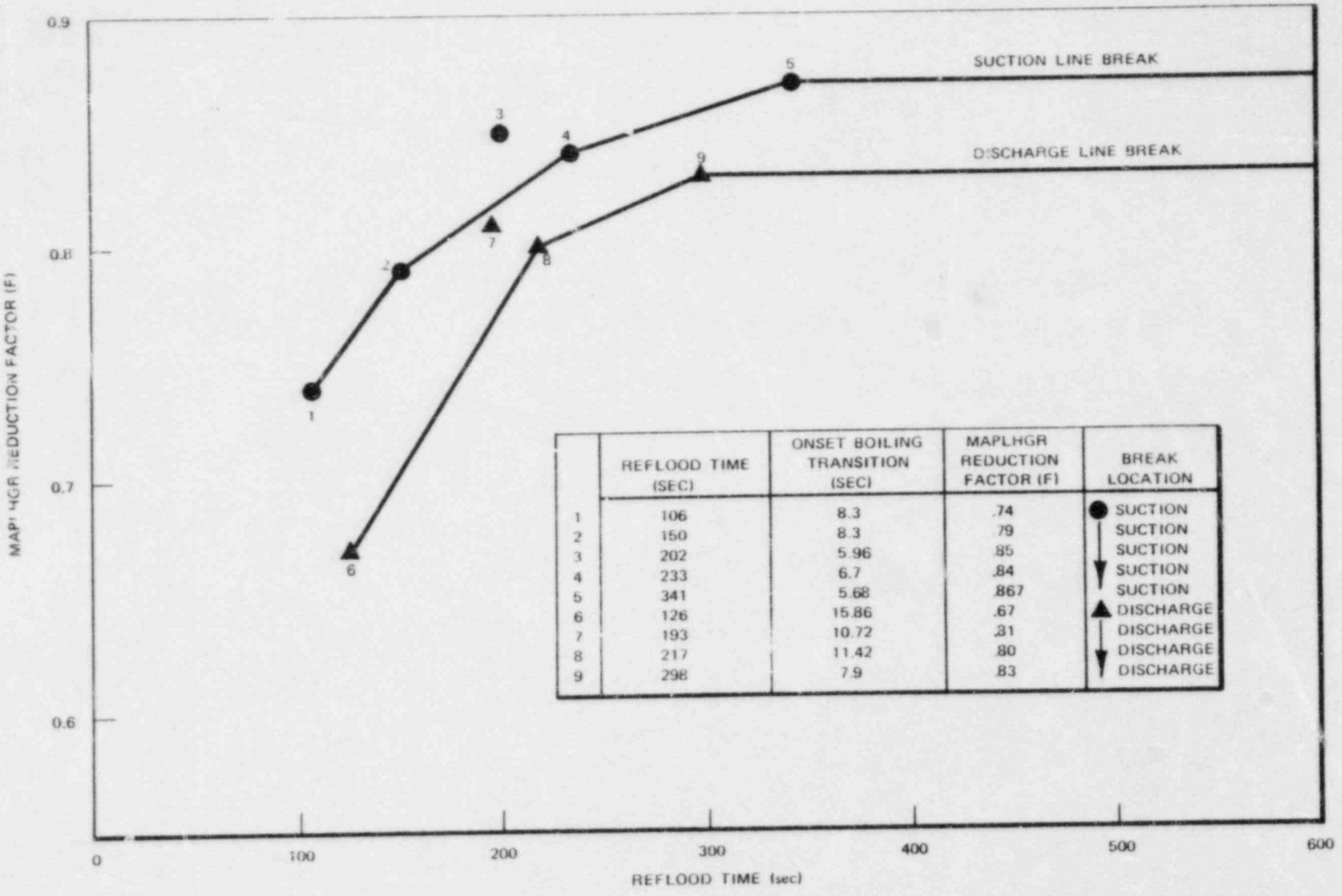
2.2.4 MAPLHGR Reduction Factor

The calculated MAPLHGR reduction factors for the selected plants are shown in Figure 1. Curves for both suction and discharge breaks are presented because the onset of boiling transition occurs significantly earlier for discharge breaks. Therefore, MAPLHGR's limited by the discharge break are more severely reduced for one pump operation.

As explained in Subsection 2.2.3, the MAPLHGR reduction factor is calculated at certain invervals of reflooding time for the BWR/3's and BWR/4's with the longest time to boiling transition for two-pump operation. Points 3 (suction break) and 7 (discharge break), shown in Figure 1, are evaluated for plants with shorter boiling transition times relative to the plants used to calculate the recommended curves for MAPLHGR reduction. The MAPLHGR reduction factors for points 3 and 7 are approximately 3% higher than those predicted by the conservative curves in Figure 1. This demonstrates the conservatism in the MAPLHGR reduction factor for plants with shorter boiling transition times.

The MAPLHGR correction factor in Figure 1 is assumed to be constant for suction break reflooding times greater than 341 sec and for discharge break reflooding times greater than 298 sec. These are the longest reflooding times for which specific calculations were performed for the respective cases. This assumption results in conservatively low one-pump MAPLHGR's in this region of constant MAPLHGR reduction because the MAPLHGR reduction is not as severe for longer reflood times.

The correction factor (F) plotted in Figure 1 is calculated from the results of the one-pump and two pump heatup analysis (MAPLHGR and PCT) according to:



	REFLOOD TIME (SEC)	ONSET BOILING TRANSITION (SEC)	MAPLHGR REDUCTION FACTOR (F)	BREAK LOCATION
1	106	8.3	.74	● SUCTION
2	150	8.3	.79	SUCTION
3	202	5.96	.85	SUCTION
4	233	6.7	.84	SUCTION
5	341	5.68	.867	SUCTION
6	126	15.86	.67	▲ DISCHARGE
7	193	10.72	.31	DISCHARGE
8	217	11.42	.80	DISCHARGE
9	298	7.9	.83	DISCHARGE

Figure 1. MAPLHGR Reduction Factor Versus Reflood Time

$$F = 1 - \left[\frac{\text{MAPLHGR (2 Pump)} - \text{MAPLHGR (1 Pump)}}{\text{MAPLHGR (2 Pump)}}\right]$$

$$- \left[\frac{2200°\text{F} - \text{PCT (2 Pump)}}{20°\text{F}}\right] \times 0.01$$

where the second bracketed term is required if the two-pump MAPLHGR is not limited by 2200°F Appendix K peak cladding temperature limit [in the general case, PCT (2 Pump) = 2200°F]. Heatup calculations have been performed to justify the assumption that a 1% change in MAPLHGR changes the calculated PCT by approximately 20°F. This assumption results in a conservatively high MAPLHGR reduction factor.

The MAPLHGR reduction factors shown in Figure 1 are calculated at the exposure which results in the most severe reduction from the two-pump case. Therefore, applying the correction factor to MAPLHGR's at all exposures results in conservatively low MAPLHGR's for one-pump operation.

Figure 1 is used to calculate MAPLHGR's for one-pump operation in the following manner. The MAPLHGR reduction factor is determined as a function of reflooding time from Figure 1. The one-pump MAPLHGR's are calculated from the available two-pump MAPLHGR's according to: MAPLHGR (1 Pump) = [F x MAPLHGR (2 Pump)]. If the calculated peak cladding temperature (PCT) for the two-pump MAPLHGR is less than 2200°F, no credit is taken for this margin (2200°F - PCT) in the calculation of the one-pump MAPLHGR.

This conservative choice is made to divorce the correction factor calculation from the temperature/power derivative which can vary significantly because of nonlinear temperature effects and (for 7x7 fuel) perforation effects.

For BWR/3's and BWR/4's without the LPCI modification, the two-pump MAPLHGR's are limited by the suction line break. Since the reflooding time for the suction break is longer than for the discharge break, the MAPLHGR's for one-pump operation will also be limited by the suction break.* For plants without the LPCI modification, the MAPLHGR reduction factor will be reported. The one-pump

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*The assumption of boiling transition at 0.1 second is identical for both suction and discharge breaks for one pump operation; therefore, since the reflooding time is longer for the suction break, the suction break limits the MAPLHGR.

MAPLHGR's are calculated by simply multiplying the two-pump MAPLHGR by the reduction factor.

For plants with the LPCI modification, the two-pump MAPLHGR's are always calculated for both the suction and discharge breaks. The more limiting MAPLHGR of the two is reported and is used as the operating limit. For plants with the LPCI modification the limiting break location may change from suction-side to discharge-side (or vice-versa) for the LOCA from one-pump operation. If this is the case, one-pump MAPLHGR's for all in-core fuel types will be supplied for the limiting DBA from one-pump operation. If the limiting break location does not change for one-pump operation, the MAPLHGR reduction factor will be supplied. The one-pump MAPLHGR can then be calculated from the two-pump MAPLHGR.

2.2.5 Break Spectrum Peak Cladding Temperature

This section provides the justification that the calculated Peak Cladding Temperature (PCT) decreases with decreasing break area from the DBA. To verify this the following generic approach is taken. The peak cladding temperature for the plant with the earliest reflooding time among all BWR/3's and BWR/4's is calculated for the DBA, 80% DBA, 60% DBA, and 1.0 ft^2 breaks for both two-pump and one-pump operation. The two-pump and one-pump MAPLHGR's used in the calculation are the maximum values over the exposure spectrum for the example plant. The assumptions for these heatup calculations are the same as for the DBA as described in Subsection 2.2.3. The most noteworthy of these assumptions is that boiling transition occurs at 0.1 sec after the postulated accident, with the Ellion pool boiling correlation used to calculate the blowdown heat transfer thereafter until core uncovery.

The plant with the earliest reflooding time is selected for the calculations because the differences between the one-pump and the two-pump calculated PCT's for the large* breaks are maximum for the following reason. For two-pump operation in this plant the time to the onset of boiling transition for the large breaks is maximum relative to the DBA. In other words, the heat transfer prior to boiling transition is maximum relative to the DBA. Therefore, the assumption

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*The large breaks are defined as 80% DBA, 60% DBA, and 1 ft^2.

of early boiling transition for one-pump operation increases the large break PCT's relative to the DBA PCT (generally equal to the Appendix K PCT limit, 2200°F), i.e., the break spectrum PCT values more closely approach the DBA PCT limit.

A comparison of the calculated PCT's for the large breaks is shown in Table 2-3 for one-pump and two-pump operation. It will be noted that the calculated PCT's for large breaks are always less than 2200°F.

These results are applied generically to the BWR/3's lead plant (Quad Cities) break spectrum PCT curves by adding the difference between the one-pump and two-pump PCT's (ΔPCT from last column in Table 2-3) to the corresponding large break PCT for two-pump operation. This establishes an upper limit on the large break PCT's for one-pump operation. In other words, the large break PCT's for one-pump operation will always be less than or equal to the sum of the corresponding PCT for two-pump operation and the corresponding PCT difference calculated for the example plant. This is because the ΔPCT calculated for the example plant is the maximum expected among all BWR/3's and BWR/4's. For Quad Cities, the upper limit on the large break PCT's is always less than the 2200°F

Table 2-3

COMPARISON OF ONE PUMP AND TWO PUMP CALCULATED PEAK CLADDING TEMPERATURES FOR LARGE BREAKS FOR THE BWR/3-BWR/4 WITH THE EARLIEST REFLOODING TIME*

BREAK	TWO-PUMP OPERATION PCT (°F)	ONE-PUMP OPERATION PCT (°F)	ΔPCT (ONE-PUMP VERSUS TWO PUMP) (°F)
DBA	2200	2200	0
80% DBA	2125	2150	25
60% DBA	2035	2115	80
1 ft^2	1730	1925	195

*MAPLHGR for two pump operation = 16.1 kW/ft
MAPLHGR for one pump operation = 12.7 kW/ft

DBA PCT. Since the Quad Cities results exemplify the calculational results for all BWR/3's this conclusively demonstrates that the large break PCT's will always be less than the DBA PCT for Pilgrim.

Consideration is also given to breaks smaller than 1.0 ft^2. A representative calculation for the highest small (0.07 ft^2) break PCT among all BWR/3's and BWR/4's was performed using the one pump operation heatup assumptions (early boiling transition followed by Ellion pool boiling until core uncovery) specified in Subsection 2.2.3. The calculated PCT's for two-pump and one-pump operation are 1725°F, and 1760°F, respectively. Compared to the 1 ft^2 break, the difference in PCT for this example calculation is relatively small (35°F versus 195°F) because the one pump MAPLHGR is reduced by 15% from the two-pump case, and because the hot node is covered for a relatively long time (250 versus 85 sec) prior to uncovery. The heat transfer calculated from the Ellion correlation tends to compensate for the early boiling transition.

An additional effect which would minimize the small break PCT increase for one-pump operation is that there is significant recirculation pump coastdown flow for the smaller break. A rough calculation to estimate the coastdown flow due to natural circulation only was performed for a 1.0 ft^2 break in the operating loop. The component of coastdown flow due to the driving flow from the broken loop (much of which is lost out the break) is ignored. The calculation shows that the coastdown flow through the core decays from 60% of rated flow (typically 17,000 lb/sec for a 251-BWR/4) for one-pump operation to approximately 13% of the rated flow (approximately 3700 lb/sec) within 10 sec after the accident. This would result in a significant delay (at least several seconds) in the onset of boiling transition at 0.1 sec for the 1.0 ft^2 PCT calculation. For breaks smaller than 1.0 ft^2, the break flow reduces the coastdown flow to a lesser degree because the driving flow in the broken loop is not completely lost out of the break. Therefore, the onset of boiling transition is further retarded for smaller breaks. Thus, for small breaks, the LOCA from one-pump operation resembles the two-pump LOCA and the assumption of early boiling transition becomes unrealistically conservative. Therefore, as is the case for two-pump operation in all BWR/3's and BWR/4's, calculated PCT's for small breaks remain well below the 2200°F limit.

2.2.6 Limiting Single Failure and "Worst" Break Location

For BWR/3's and BWR/4's without the LPCI modification, the single failure which is most limiting on MAPLHGR remains unchanged in going from two-pump to one-pump operation. This is true because the limiting single failure for either case is that which results in the longest reflooding time. Since the reflooding time is the same for both two-pump and one-pump operation (as justified in Subsection 2.2.2), the limiting single failure is identical for both cases.

For plants with the LPCI modification the MAPLHGR's for both suction break and discharge break are calculated for both two-pump and one-pump operation. The more limiting MAPLHGR (suction or discharge) is reported. The most limiting single failure for both suction break and discharge break remains unchanged in going from two-pump to one-pump operation, as discussed above.

Under no circumstances can a break in the idle loop (equalizer valve is assumed closed) be more limiting than a break in the operating loop. For a break in the idle loop there will be normal coastdown flow from the intact loop. This results in the break being much less severe than the limiting DBA in the operating loop for which no coastdown flow is assumed. An additional consideration is that if the inoperative recirculation pump is isolated by the suction and discharge shut-off valves, the break area for either suction-side or discharge-side breaks is always less than the DBA break area assumed for the calculation of one-pump MAPLHGR's in this report. This is because one or both (trivial case) sides of the break will be isolated from the vessel. Since the break area is smaller, this accident is less limiting than the DBA in the operating loop. The break spectrum arguments in Section 2.2.5 substantiate this conclusion.

2.3 RESULTS FOR PILGRIM CYCLE 2

With two pumps operating, the Pilgrim MAPLHGR is limited by the suction break with the reflooding time given in Reference 4. This is also the limiting DBA for one-pump operation. The corresponding MAPLHGR reduction factor from Figure 1 is 0.867. The MAPLHGR limits for one-pump operation are obtained by multiplying the two-pump MAPLHGR limits from Reference 4 by this factor. These are shown for all Pilgrim fuel types in Figures 2B.1-2B.7.

The corresponding peak cladding temperature and the maximum local metal-water reaction are shown in Figures 2A.1-2A.7. The MAPLHGR limits are valid for plugged core plate holes and for single-loop operation with the recirculation equalizer valve closed.

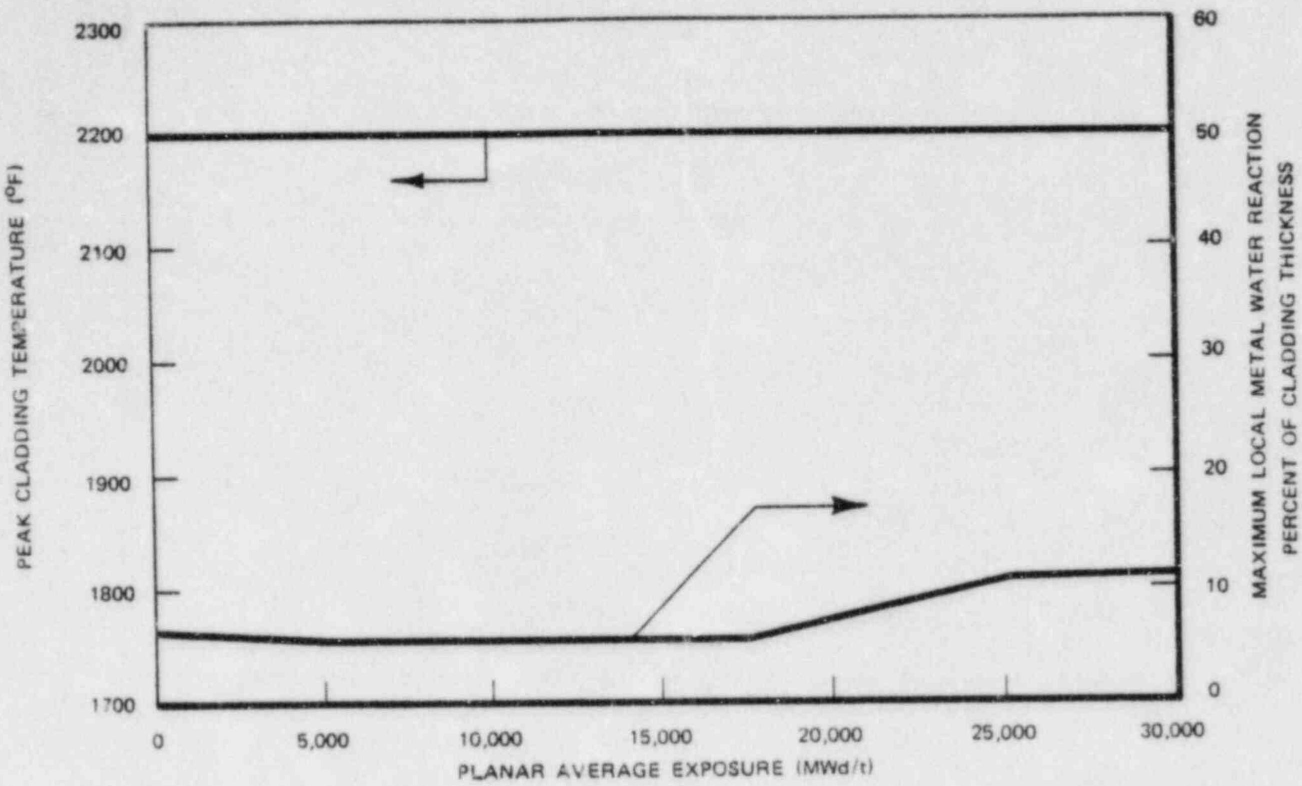

Figure 2A.1. Peak Cladding Temperature and Maximum Local Metal-Water Reaction versus Planar Average Exposure, Pilgrim NPS Unit 1, Initial Core - No Curtains, Single-Loop Operation, Plugged Bypass Holes, Recirculation Equalizer Valve Closed

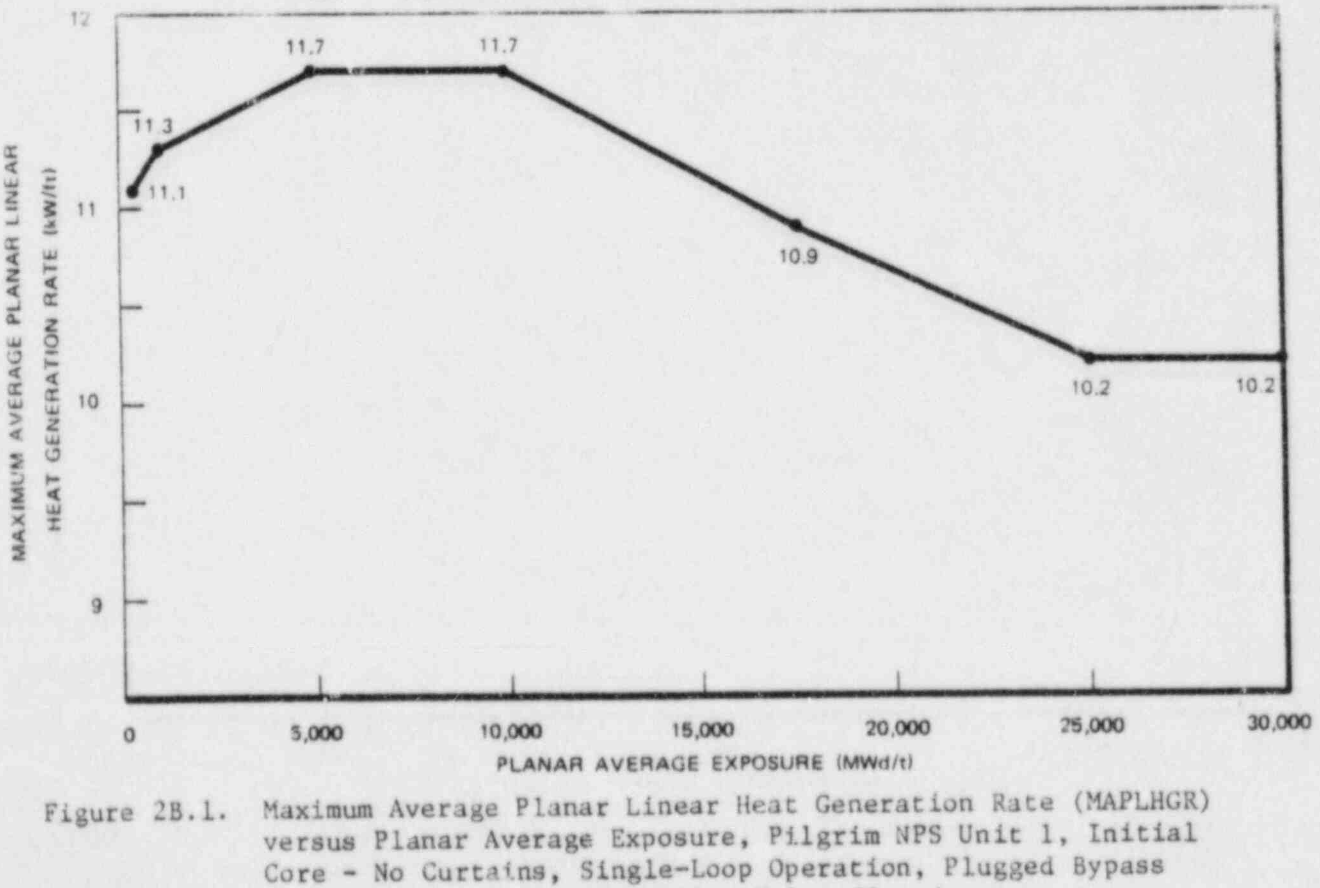

Figure 2B.1. Maximum Average Planar Linear Heat Generation Rate (MAPLHGR) versus Planar Average Exposure, Pilgrim NPS Unit 1, Initial Core - No Curtains, Single-Loop Operation, Plugged Bypass Holes, Recirculation Equalizer Valve Closed

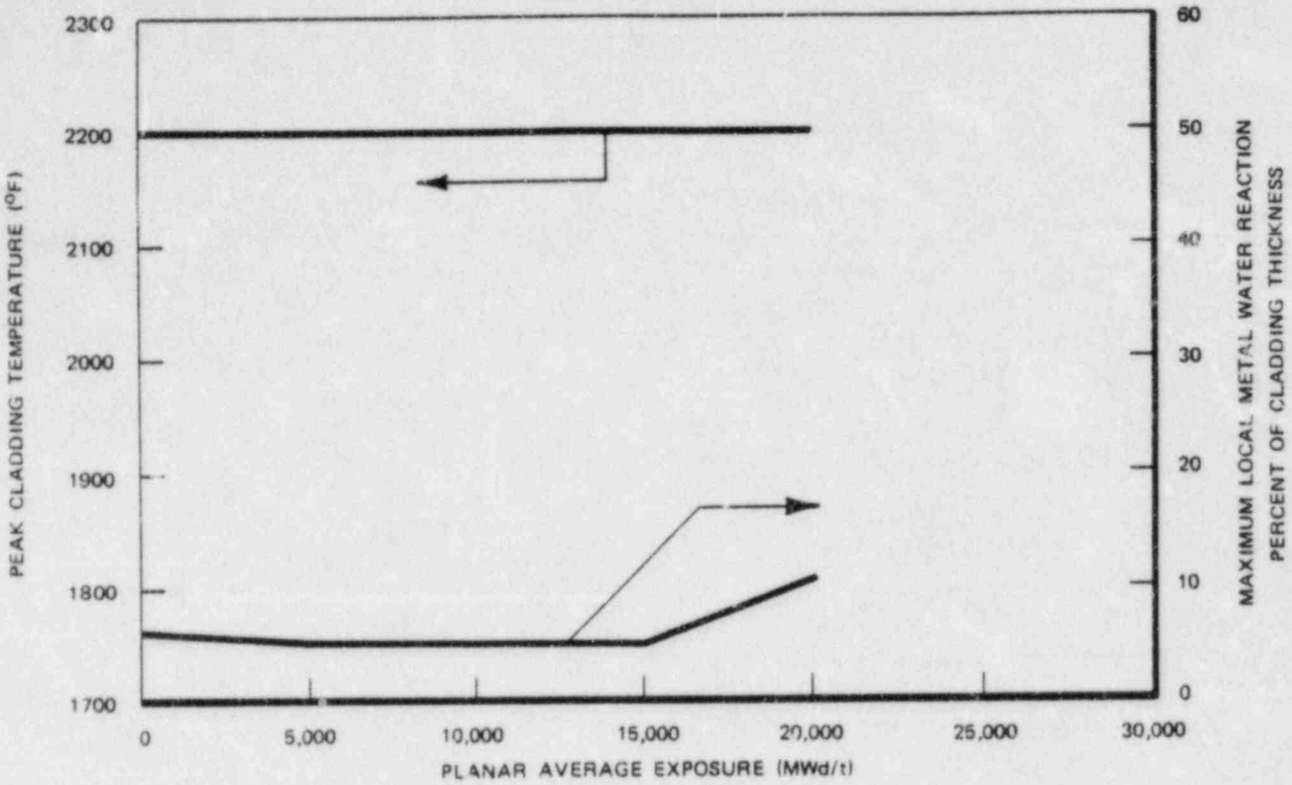

Figure 2A.2. Peak Cladding Temperature and Maximum Local Metal-Water Reaction versus Planar Average Exposure, Pilgrim NPS Unit 1, Initial Core - 1 Weak Curtain, Single-Loop Operation, Plugged Bypass Holes, Recirculation Equalizer Valve Closed

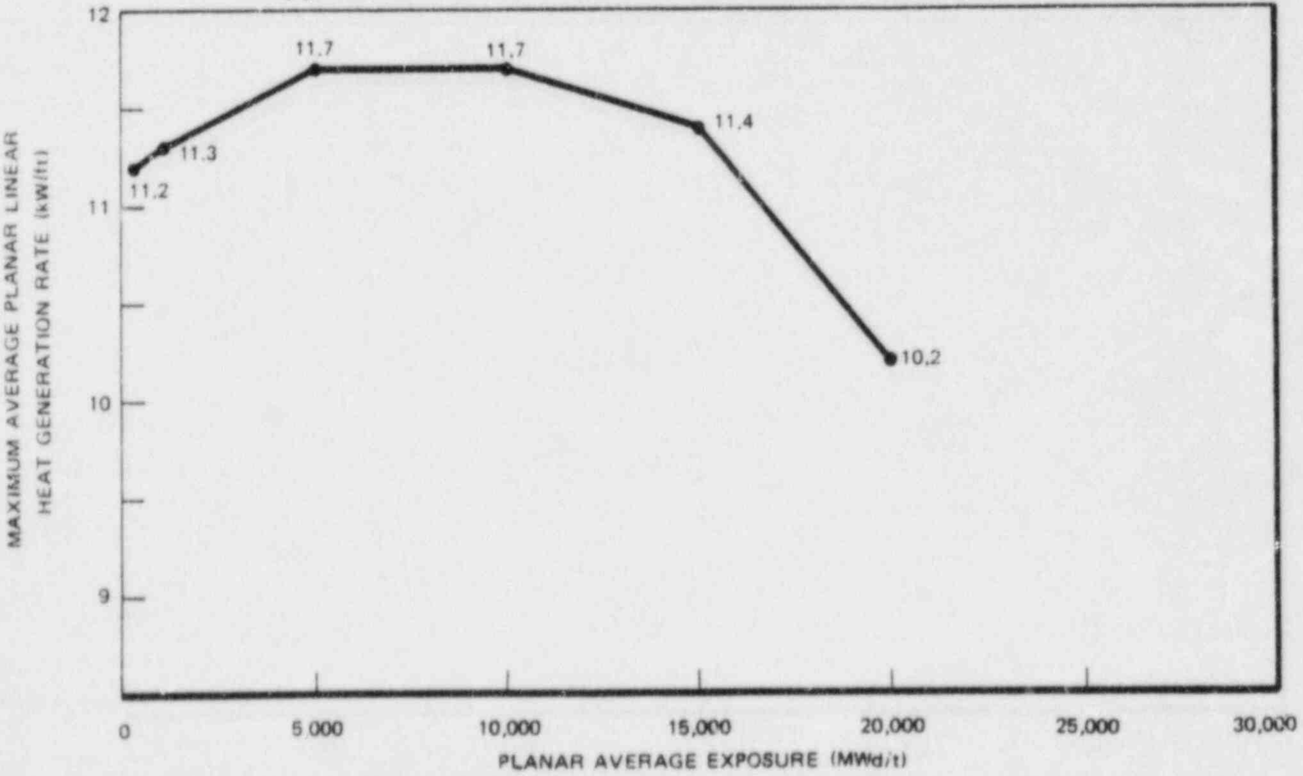

Figure 2B.2. Maximum Average Planar Linear Heat Generation Rate (MAPLHGR) versus Planar Average Exposure, Pilgrim NPS Unit 1, Initial Core - 1 Weak Curtain, Single-Loop Operation, Plugged Bypass Holes, Recirculation Equalizer Valve Closed

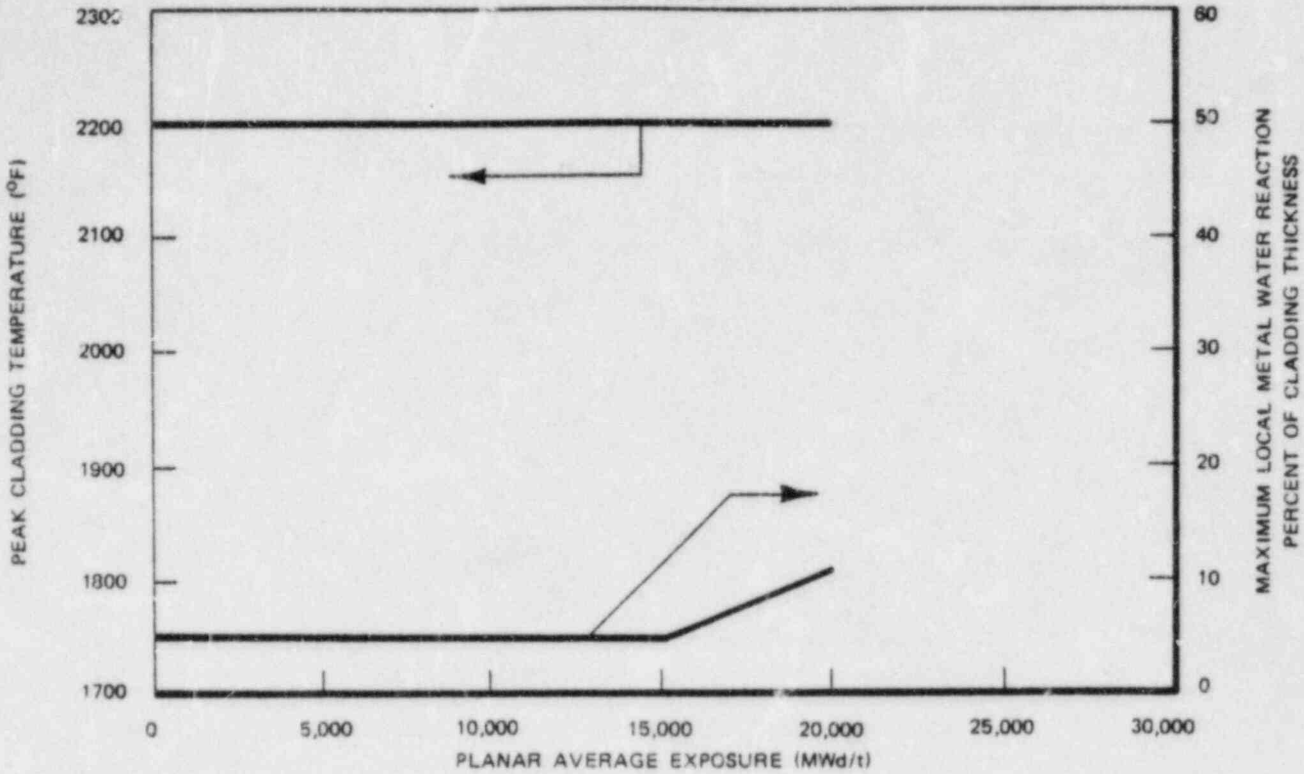

Figure 2A.3. Peak Cladding Temperature and Maximum Local Metal-Water Reaction versus Planar Average Exposure, Pilgrim NPS Unit 1, Initial Core - 2 Weak Curtains, Single-Loop Operation, Plugged Bypass Holes, Recirculation Equalizer Valve Closed

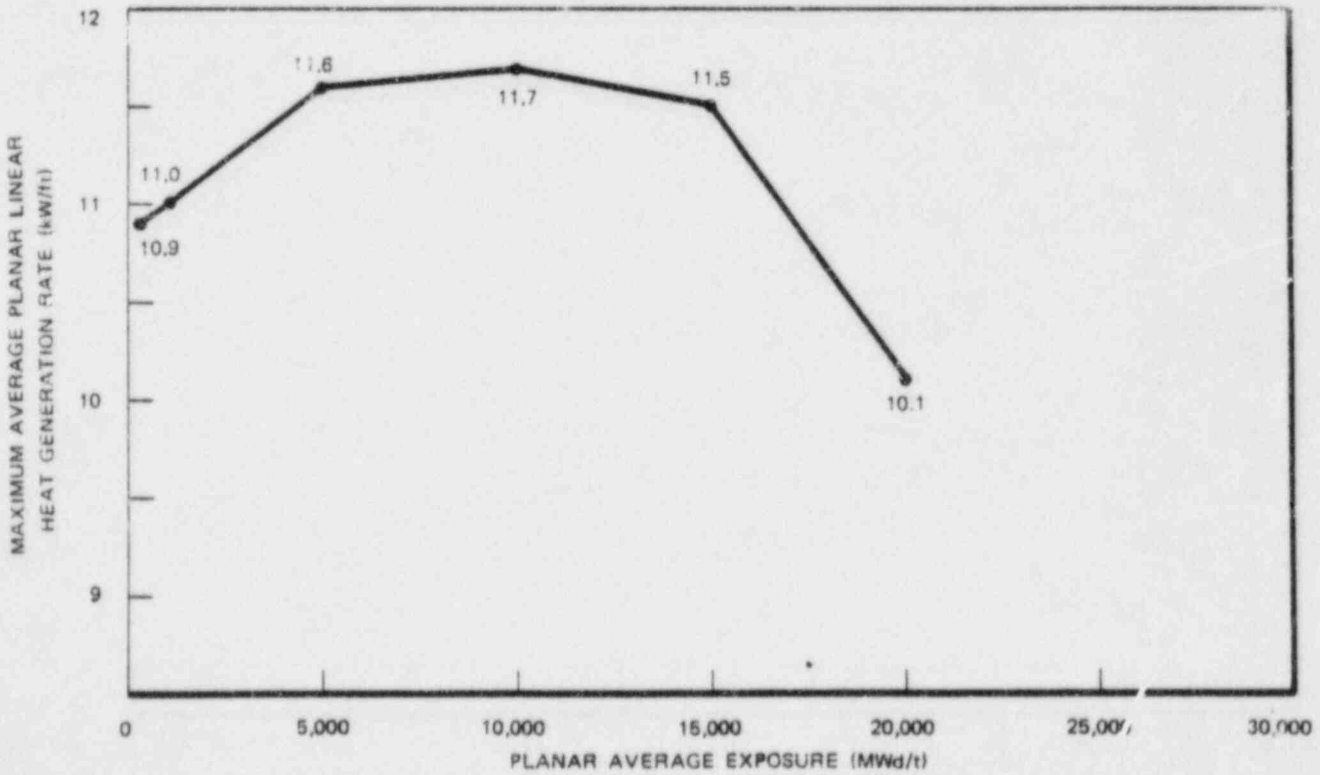

Figure 2B.3. Maximum Average Planar Linear Heat Generation Rate (MAPLHGR) versus Planar Average Exposure, Pilgrim NPS Unit 1, Initial Core - 2 Weak Curtains, Single-Loop Operation, Plugged Bypass Holes, Recirculation Equalizer Valve Closed

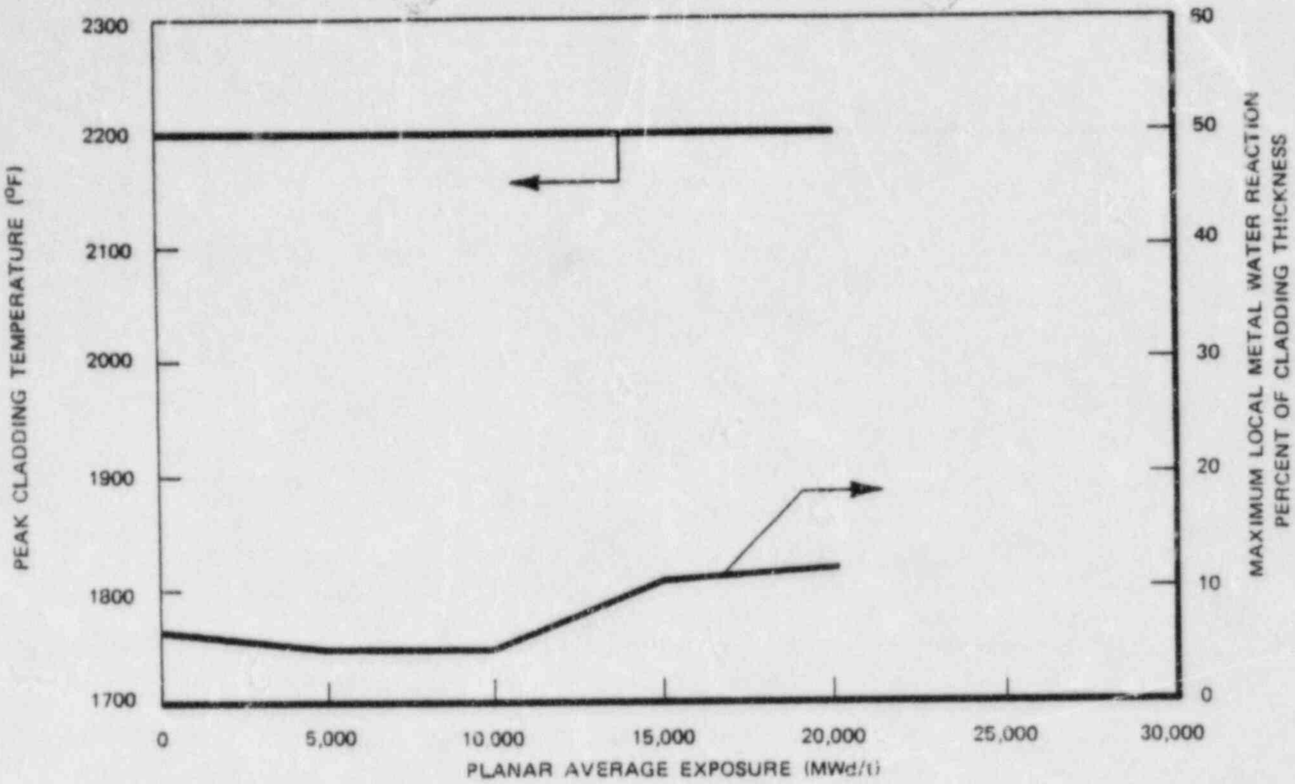

Figure 2A.4. Peak Cladding Temperature and Maximum Local Metal-Water Reaction versus Planar Average Exposure, Pilgrim NPS Unit 1, Initial Core - 1 Weak Curtain, 1 Strong Curtain, Single-Loop Operation, Plugged Bypass Holes, Recirculation Equalizer Valve Closed

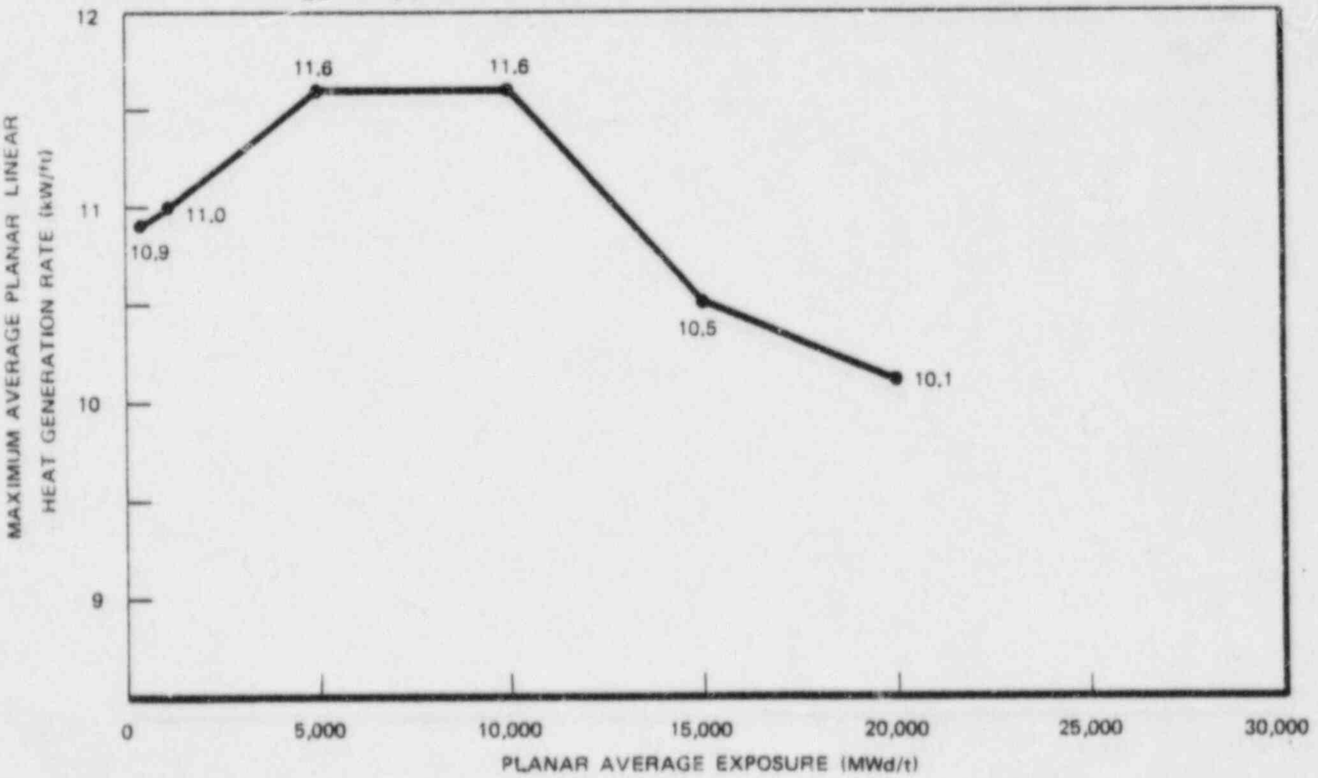

Figure 2B.4. Maximum Average Planar Linear Heat Generation Rate (MAPLHGR) versus Planar Average Exposure, Pilgrim NPS Unit 1, Initial Core - 1 Weak Curtain, 1 Strong Curtain, Single-Loop Operation, Plugged Bypass Holes, Recirculation Equalizer Valve Closed

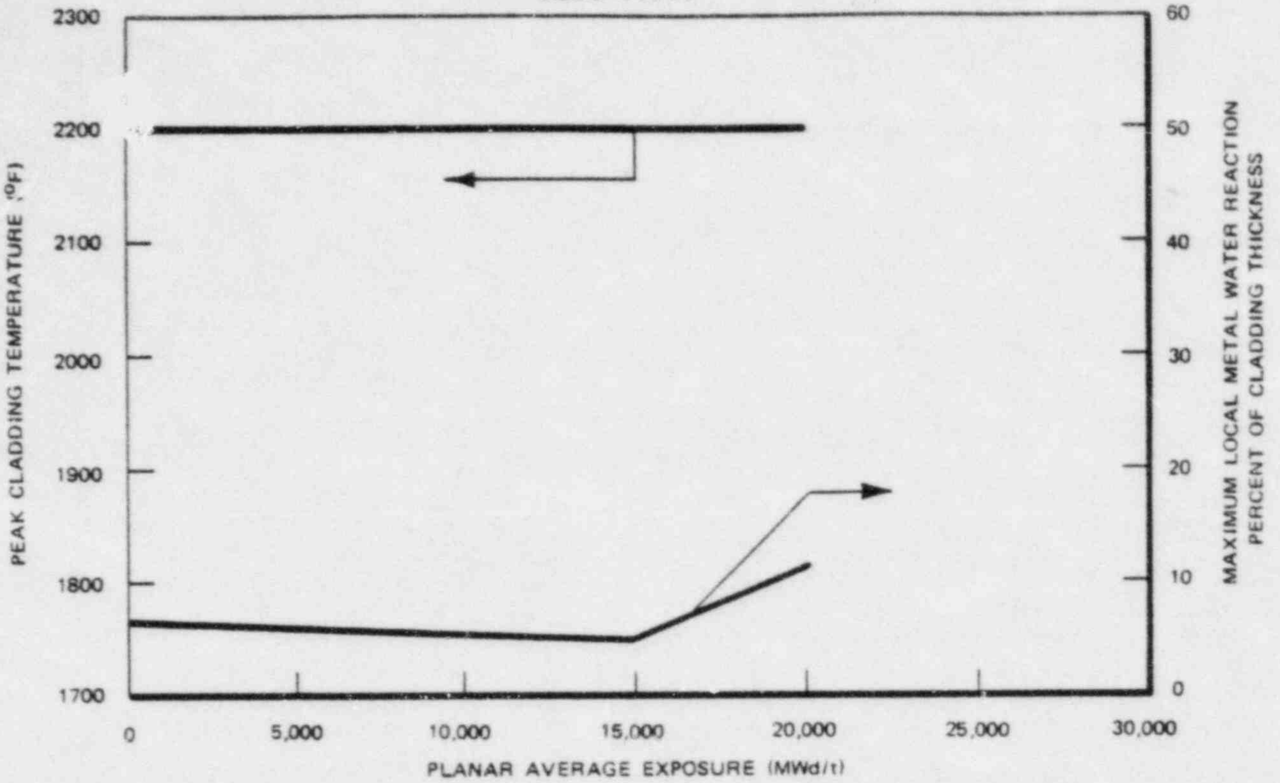

Figure 2A.5. Peak Cladding Temperature and Maximum Local Metal-Water Reaction versus Planar Average Exposure, Pilgrim NPS Unit 1, Initial Core - 1 Strong Curtain, Single-Loop Operation, Plugged Bypass Holes, Recirculation Equalizer Valve Closed

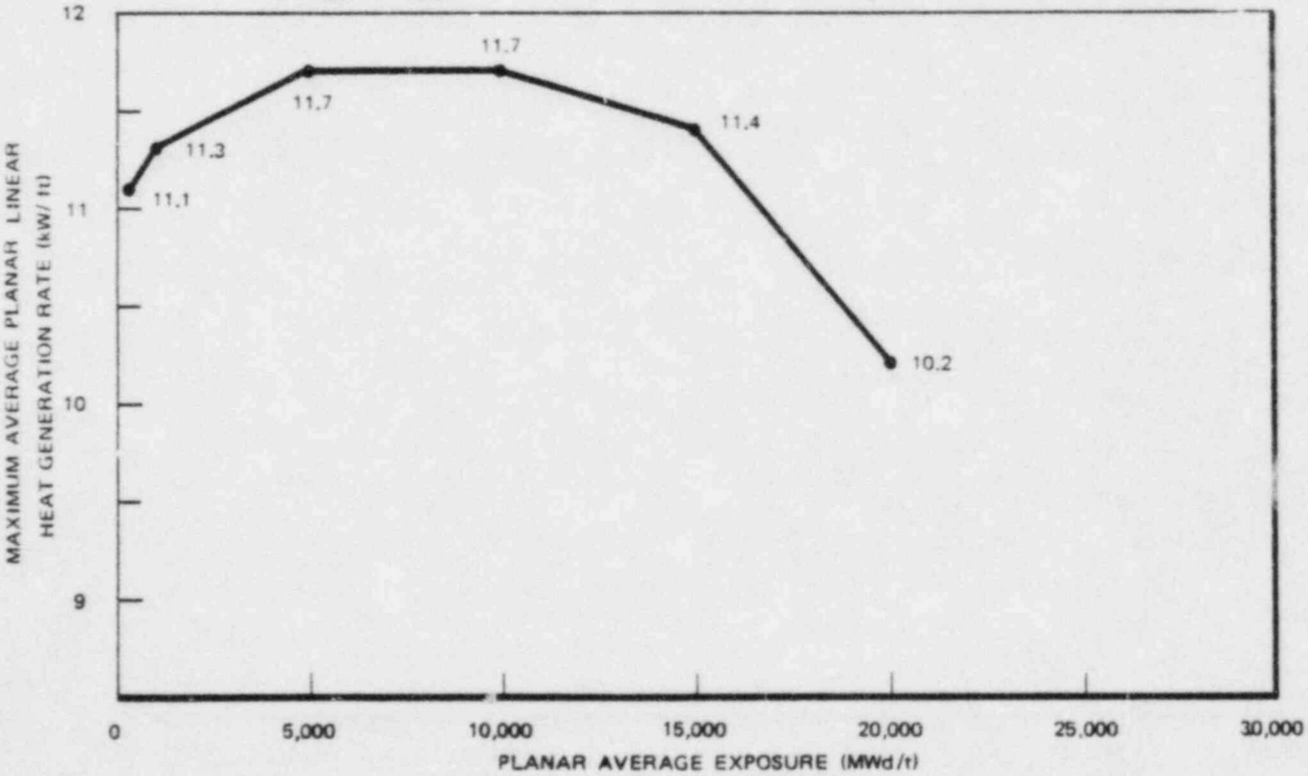

Figure 2B.5. Maximum Average Planar Linear Heat Generation Rate (MAPLHGR) versus Planar Average Exposure, Pilgrim NPS Unit 1, Initial Core - 1 Strong Curtain, Single-Loop Operation, Plugged Bypass Holes, Recirculation Equalizer Valve Closed

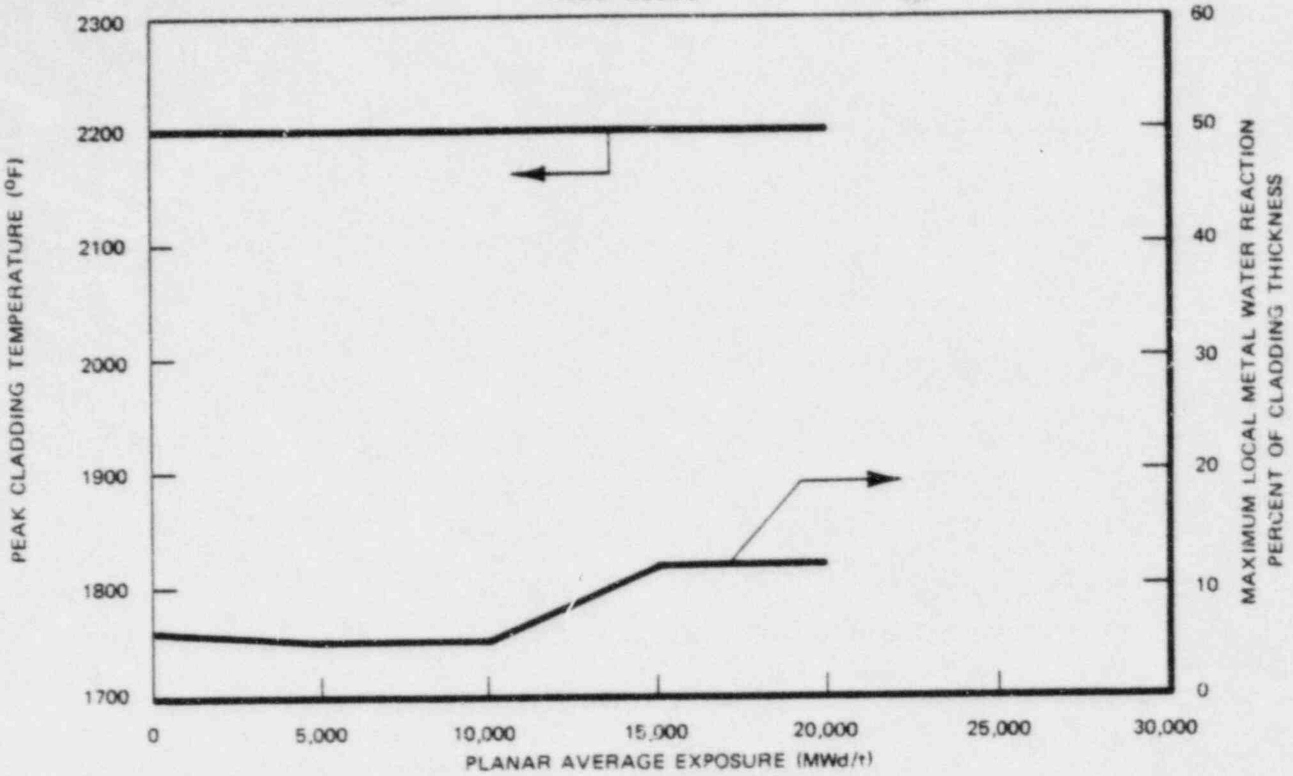

Figure 2A.6. Peak Cladding Temperature and Maximum Local Metal-Water Reaction versus Planar Average Exposure, Pilgrim NPS Unit 1, Initial Core - 2 Strong Curtains, Single-Loop Operation, Plugged Bypass Holes, Recirculation Equalizer Valve Closed

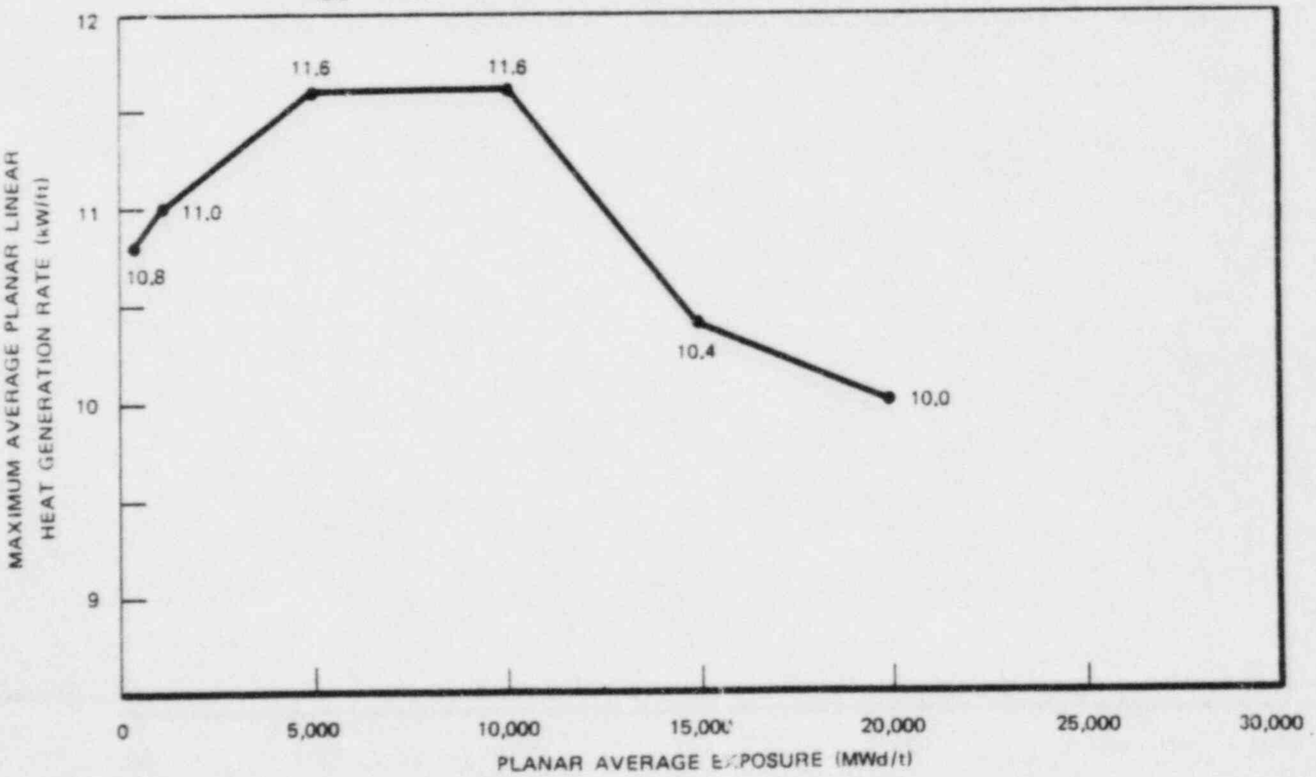

Figure 2B.6. Maximum Average Planar Linear Heat Generation Rate (MAPLHGR) versus Planar Average Exposure, Pilgrim NPS Unit 1, Initial Core - 2 Strong Curtains, Single-Loop Operation, Plugged Bypass Holes, Recirculation Equalizer Valve Closed

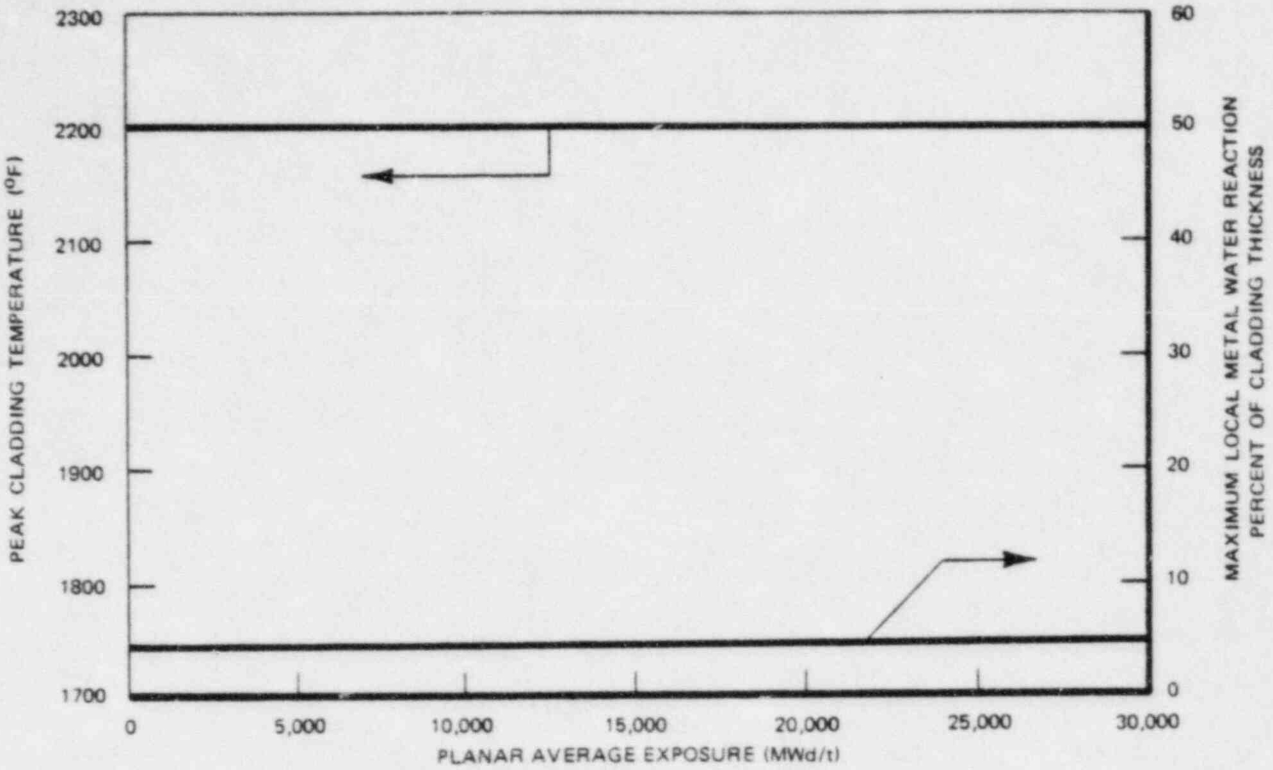

Figure 2A.7. Peak Cladding Temperature and Maximum Local Metal-Water Reaction versus Planar Average Exposure, Pilgrim NPS Unit 1, 8D262 Fuel, Single-Loop Operation, Plugged Bypass Holes, Recirculation Equalizer Valve Closed

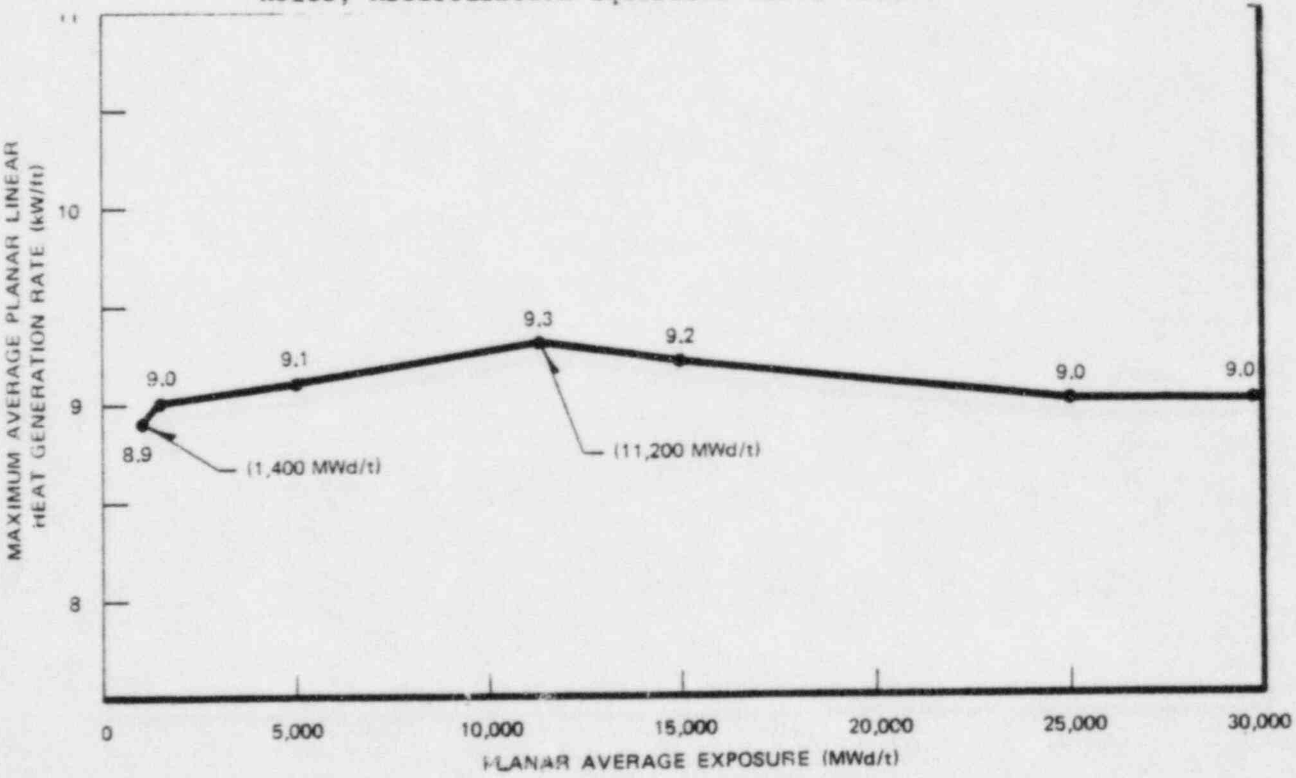

Figure 2B.7. Maximum Average Planar Linear Heat Generation Rate (MAPLHGR) versus Planar Average Exposure, Pilgrim NPS Unit 1, 8D262 Fuel, Single-Loop Operation, Plugged Bypass Holes, Recirculation Equalizer Valve Closed

3. ONE-PUMP SEIZURE ACCIDENT

The pump seizure event is a very mild accident in relation to other accidents such as the LOCA. This has been demonstrated by analyses in Reference 2 for the case of two-pump operation, and that it is also true for the case of one-pump operation is easily verified by consideration of the two events. In both accidents, the recirculation driving loop flow is lost extremely rapidly: in the case of the seizure, stoppage of the pump occurs; for the LOCA, the severance of the line has a similar, but more rapid and severe influence. Following a pump seizure event, natural circulation flow continues, water level is maintained, the core remains submerged, and this provides a continuous core cooling mechanism. However, for the LOCA, complete flow stoppage occurs and the water level decreases due to loss-of-coolant resulting in uncovery of the reactor core and subsequent overheating of the fuel rod cladding. In addition, for the pump seizure accident, reactor pressure does not decrease, whereas complete depressurization occurs for the LOCA. Clearly, the increased temperature of the cladding and reduced reactor pressure for the LOCA both combine to yield a much more severe stress and potential for cladding perforation for the LOCA than for the pump seizure. Therefore, it can be concluded that the potential effects of the hypothetical pump seizure accident are very conservatively bounded by the effects of a LOCA and specific analyses of the pump seizure accident are not required.

4. ABNORMAL OPERATIONAL TRANSIENTS

4.1 TRANSIENTS AND CORE DYNAMICS

Since operation with one recirculation loop results in a maximum power output which is 20 to 30% below that from which can be attained for two-pump operation, the consequences of abnormal operational transients from one-loop operation will be considerably less severe than those analyzed from a two-loop operational mode.

For pressurization, cold water and flow decrease, transients previously transmitted Reload/FSAR results bound both the thermal and overpressure consequences of one-loop operation. Figure 3 shows the consequences of a typical pressurization transient (turbine trip) as a function of power level. As can be seen, the consequences of one-loop operation are considerably less because of the associated reduction in operating power level. The thermal (MCPR) consequences from cold water events and flow decrease transients are also bounded by the full power analysis. For example, a single pump trip from one-loop operation is obviously less severe than a two-pump trip from full power because of the reduced initial power level. It can, therefore, be concluded that the transient consequence from one-loop operation is bounded by previously submitted full power analysis. The maximum power level that can be attained on one-loop operation is only restricted by the MCPR and overpressure limits established from a full power analysis.

4.2 ROD WITHDRAWAL ERROR

The rod withdrawal error at rated power is given in reload licensing submittals (see Reference 5 for an example). These analyses demonstrate that even if the operator ignores all indications and alarm which could occur during the course of the transient, the rod block system will stop rod withdrawal at a critical power ratio which is higher than the 1.06 safety limit. The MCPR requirement for one-pump operation will be equal to that for two-pump operation because the nuclear characteristics are independent of whether the core flow is attained by one- or two-pump operation. The only exceptions to this independence are possible flow asymmetries which might result from one-pump operation. Flow

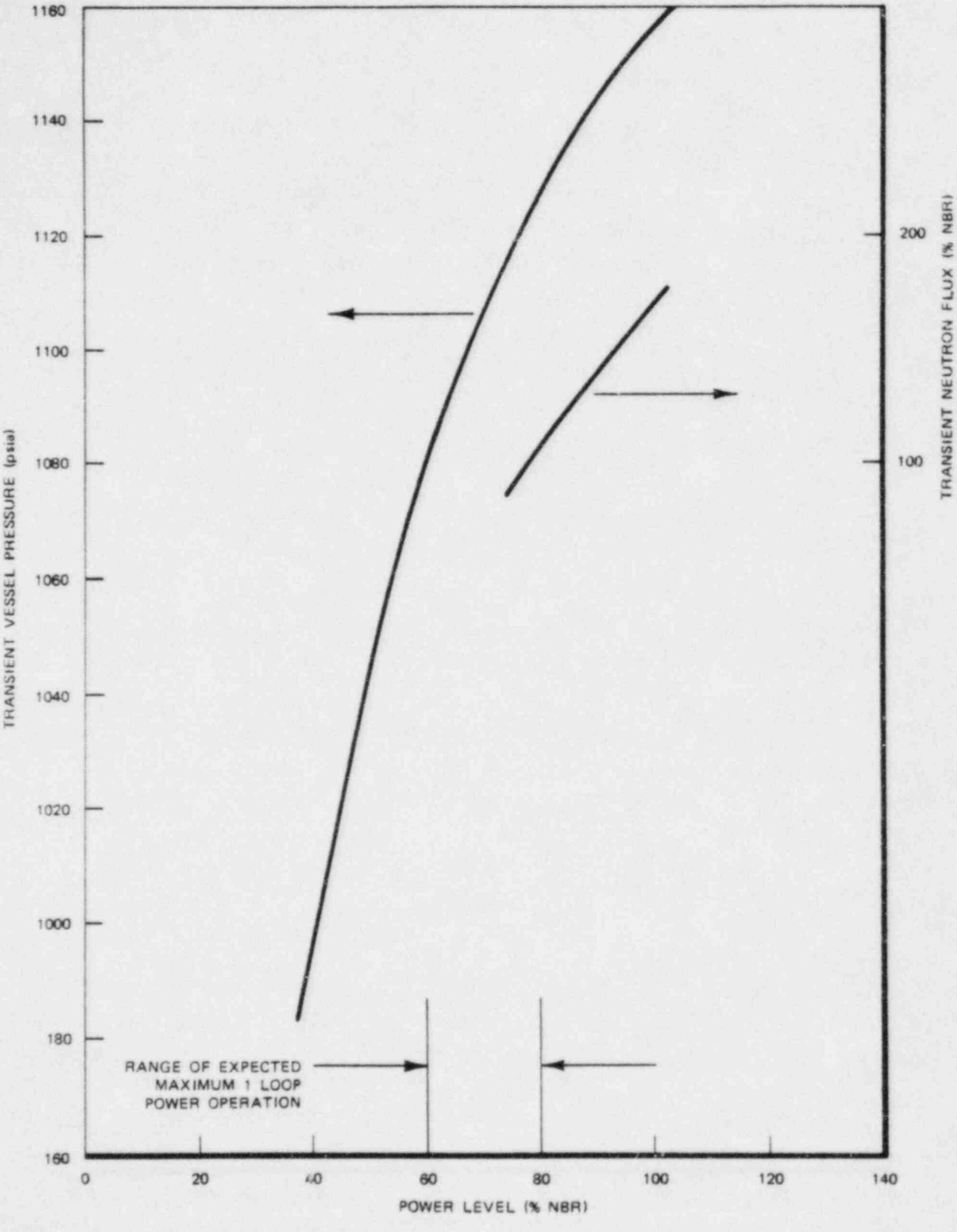

Figure 3. Main Turbine Trip with Bypass Manual Flow Control

asymmetries were shown to be of no concern by tests conducted at Quad Cities. Under conditions of one-pump operation and equalizer valve closed, flow was found to be uniform in each bundle (see Reference 6).

One-pump operation results in backflow through ten of the twenty jet pumps while the flow is being supplied into the lower plenum from the ten active jet pumps. Because of the backflow through the inactive jet pumps, the present rod block equation shown in the Technical Specifications must be modified.

The procedure for modifying the rod block equation for one-pump operation consists of the following:

1. determine the rod block upper and lower limits as stated in the Technical Specifications, i.e., rod block (RB) at drive flows (W) of 0% and 100% or RB_0 and RB_{100}, respectively;
2. derive the one-and-two-pump curves relating core flow (F_c) to drive flow (W);
3. extend the one-pump curve such that it is parallel to the two-pump curve up to a core flow of 100%;
4. record the difference in the drive flows (ΔW) associated with one-and-two-pump operation at a core flow of 100%; and
5. the new rod block equation is:

$$RB = \left(\frac{RB_{100} - RB_0}{100 + \Delta W}\right) W + RB_0$$

RB_0 of step 1 defines the constant associated with the rod block equation in that when $W = 0$, $RB = RB_0$. This, when applied to the general equation form, results in:

$$RB = mW + RB_0$$

Note that RB_0 should be the same as the present plant instrument setting.

RB_{100} of step 1 in conjunction with steps 2 to 4 will define the slope (m) of the above equation. Once the two-pump curve has been plotted so that $F_c = 100\%$ and $W = 100\%$, a one-pump curve is plotted. However, the one-pump curve will not exceed approximately 60% rated drive flow. Therefore, this curve is extended parallel to the two-pump curve up to a core flow of 100% as shown in Figure 4.

The coordinate corresponding to the intersection of the extended one-pump curve and the 100% F_c line will be applied to the above equation as follows:

$$RB_{100} = m(100 + \Delta W) + RB$$

solving for m,

$$m = \frac{RB_{100} - RB_0}{100 + \Delta W}$$

Therefore the modified equation becomes:

$$RB = \left(\frac{RB_{100} - RB_0}{100 + \Delta W}\right) W + RB_0$$

Summarizing, the constant RB_0 will remain the same for both one- and two-pump modes of operation. However, the slope will change for the one-pump condition. Therefore, changes to hardware settings should be restricted to the numerical coefficient associated with W.

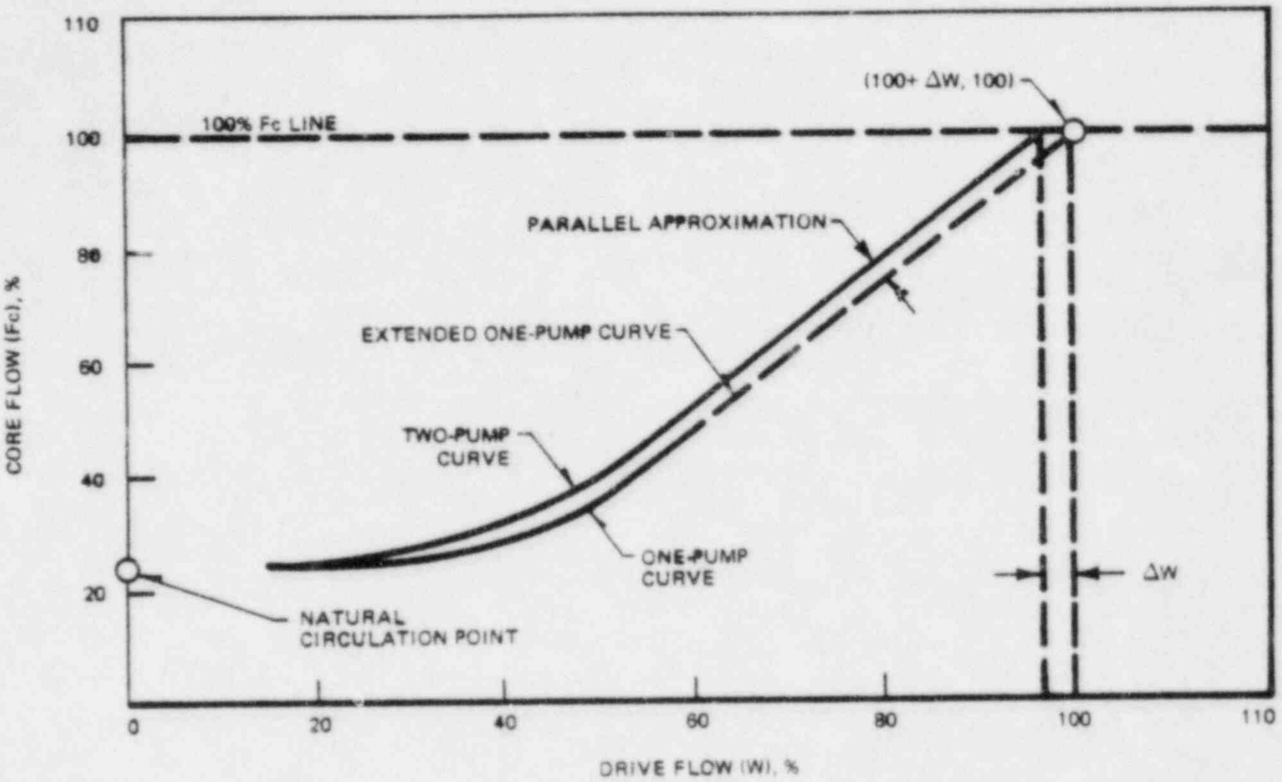

Figure 4. Core Flow Versus Drive Flow for One-and-Two-Pump Operation

5. STABILITY ANALYSES

The least stable power/flow condition attainable under normal conditions is at natural circulation with control rods set for rated power and flow. This condition might be reached following loss of both recirculation pumps. However, the plant is quite stable even at this condition. Operations with one recirculation pump running would be more stable although not as stable as with both pumps running.

Load following by flow control would be limited with one-loop operation. For normal bypass flow, the stability analysis for Pilgrim Reload 2 (Reference 5) shows that the low end of normal flow-control range to be at 39% of rated flow. Therefore, for one-loop operation, automatic flow control should be used only if the flow in the operating loop is at least 78% of rated. If the bypass holes are plugged, only manual flow control should be used.

6. REFERENCES

1. Final Safety Analysis Report, Pilgrim Nuclear Power Station; Section IV.

2. "GE/BWR Generic Reload Licensing Applications for 8x8 Fuel," Rev. 1, Supplement 3 (NEDO-20360).

3. "General Electric Company Analytical Model for Loss-of-Coolant Analysis in Accordance with 10CFR50 Appendix K" (NEDO-20566).

4. Letter from Thomas J. Galligan, Jr. (Boston Edison Co) to Director, Division of Reactor Licensing, dated July 9, 1975 transmitting Pilgrim Nuclear Power Station, Unit 1, Loss-of-Coolant Analyses Conformance with Section 50.46 and Appendix K of 10CFR50 (Plugged Bypass Holes), July 1975.

5. Reload No. 2 Licensing Submittal for Pilgrim Nuclear Power Station (Unit 1) September 1975 (NEDO-20855-1).

6. Letter from Wayne L. Stiede (Commonwealth Edison Co.) to Director, Division of Reactor Licensing, dated Feb. 17, 1972; Subject: Supplementary Information to Special Report No. 6 "Reactor Asymmetrical Neutron Flux Distribution" - Dresden Unit 2.