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Grand Gulf Unit 1 Cycle 6
Plant Transient Analysis

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GRAND GULF UNIT 1 CYCLE 6 PLANT TRANSIENT ANALYSIS

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

This report presents the results of analyses performed by Siemens Nuclear Power Corporation (SNP) for reload fuel in Grand Gulf Unit 1 Cycle 6 for operation within the Maximum Extended Operating Domain (MEOD). In Cycle 1 (Reference 1) the NSSS vendor performed extensive transient analyses for Grand Gulf Unit 1 in conjunction with the extension of the power/flow operating map to the MEOD. These analyses established conservative operating limits for MEOD operation. The initial reload of SNP fuel in Grand Gulf Unit 1 occurred in Cycle 2. In support of the initial reload of SNP fuel, extensive additional transient analyses were performed by SNP to justify the NSSS vendor operating limits and, where necessary, provide appropriate limits for SNP fuel using SNP methodologies (Reference 2).

Cycle 6 for Grand Gulf Unit 1 will include the second reload of SNP 9x9-5 fuel (Reference 15). The nominal cycle energy is 1748 GWd and the cycle length remains 18 months. The NRC approved methods employed for the Cycle 6 analysis include the CASMO-3G/MICROBURN-B codes (Reference 7), COTRANSA2 system analysis methods (Reference 5), safety limit methodology (Reference 9), and the use of the ANFB Critical Power Correlation (Reference 14) in XCOBRA and XCOBRA-T. The Cycle 6 transient analysis consists of recalculation of the limiting transients at state points having the least margin to operating limits to confirm that the effects of the Cycle 6 changes on transient results are small relative to available margin and/or establish appropriate limits. Reanalysis of the limiting transients for Cycle 6 assures that the less limiting transients which were previously addressed will continue to be protected by the established operating limits for Cycle 6. The power/flow conditions analyzed in Cycle 6 are presented in Figure 1.1. Analyses were performed at EOC-30 EFPD, at EOC, and at EOC+30 EFPD (Effective Full Power Days).

These analyses establish the Grand Gulf Unit 1 Cycle 6 Technical Specification MCPR limits at rated conditions, establish MAPLHGR limits for Cycle 6 operation, and establish revised thermal limits for off-rated conditions. Previous Grand Gulf reload analyses have demonstrated that the maximum vessel pressure for the most limiting pressurization event varies over a narrow range essentially independent of fuel design. The evaluation of these analyses shows that vessel integrity is protected during the most limiting Cycle 6 pressurization event.

The $MCPR_p$ and $MCPR_f$ limits have been revised to reflect Cycle 6 results using SNP methodology. The Grand Gulf Unit 1 power and flow dependent MCPR analyses for Cycle 6 were performed at limiting power/flow conditions. LHGR protection has been established for both 8x8 and 9x9-5 fuel in Cycle 6 at rated and off-rated conditions. Power and flow dependent LHGR limits have been established for Cycle 6 using SNP methodology.

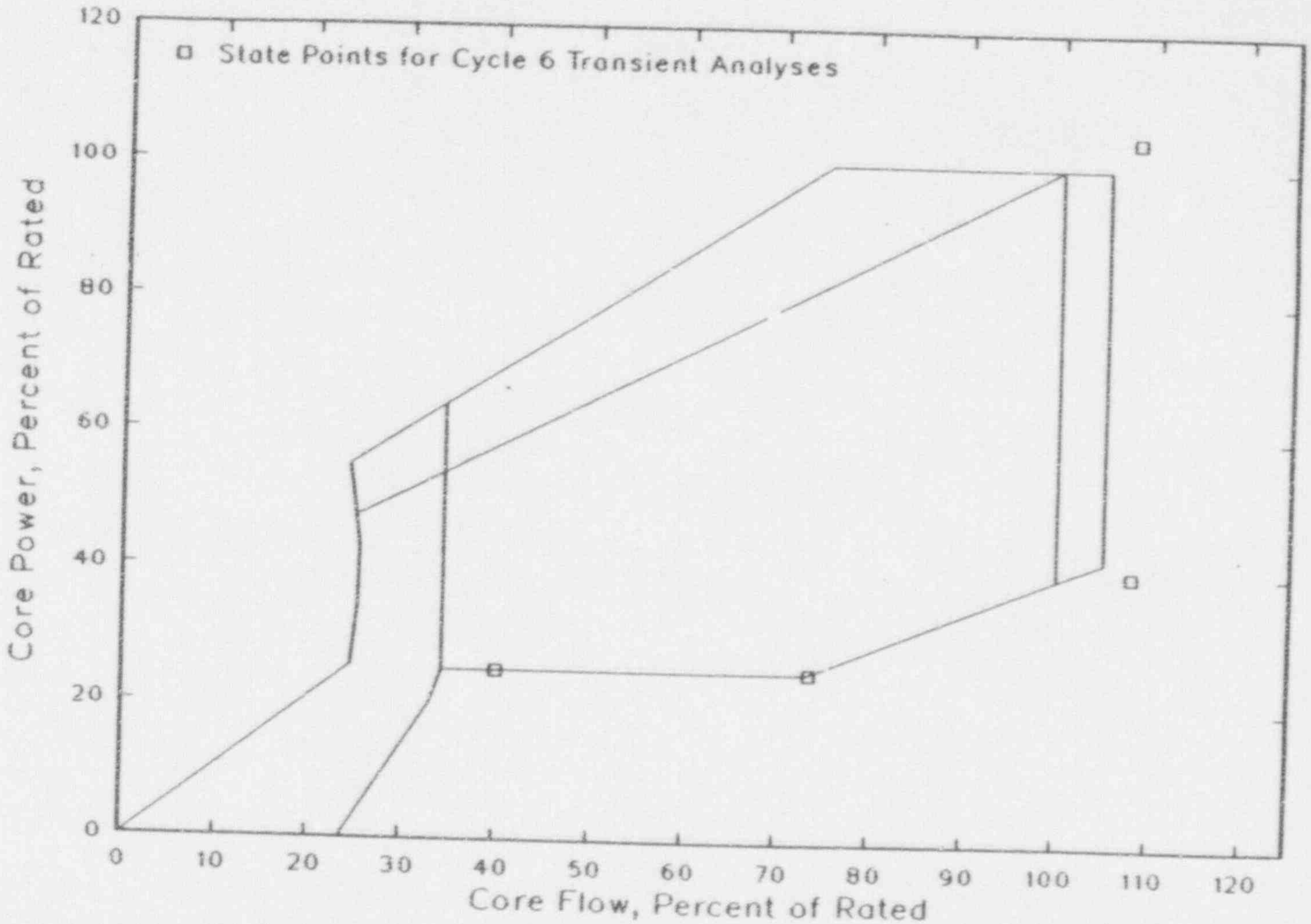

FIGURE 1.1 POWER/FLOW MAP USED FOR GRAND GULF UNIT 1 MEOD ANALYSIS

2.0 SUMMARY

The results of the Grand Gulf Unit 1 Cycle 6 transient analyses support appropriate thermal limits for the Grand Gulf core including the ANF-1.5 9x9-5 reload. SNP thermal limits have been provided for $MCPR_p$ that are based on Control Rod Withdrawal Error (CRWE) analyses and analyses for Load Reject No Bypass (LRNB) and Feedwater Controller Failure (FWCF) transients. Additionally, $MCPR_f$ limits and $LHGRFAC_f$ values (Reference 12) have been established for only the "loop manual" mode of operation. The single loop mode of operation (SLO) is evaluated in Appendix A.

The 8x8 MAPLHGR (Reference 16) and a MAPLHGR limit for 9x9-5 fuel satisfy the requirements specified by 10CFR50.46 of the U.S. Code of Federal Regulations. The 8x8 and 9x9-5 LHGR limits will be protected at off-rated conditions by applying $LHGRFAC_f$ and $LHGRFAC_p$ multipliers on the Technical Specification LHGR limits.

Table 2.1 summarizes the transient analyses results applicable to Grand Gulf Unit 1 Cycle 6. These results, together with the Grand Gulf Unit 1 Cycle 6 calculated safety limit MCPR of 1.06, support use of a 1.20 MCPR operating limit (at rated conditions) for Cycle 6 operation between BOC and EOC-30 EFPD. The operating limit (at rated conditions) from EOC-30 EFPD to EOC+30 EFPD is supported at 1.25. Figure 2.1 presents the $MCPR_e$ limit as a function of core average exposure. The calculated safety limit of 1.06 includes the assessment of the channel bow impact using appropriate SNP methods (Reference 9).

The plant transient and safety limit analyses results reported herein establish the power dependent Minimum Critical Power Ratio ($MCPR_p$) limits. The power dependent Linear Heat Generation Factor ($LHGRFAC_p$) is presented for Cycle 6 operation for SNP 8x8 and 9x9-5 fuel types. The $MCPR_p$ limits, the $LHGRFAC_p$ values, and the corresponding results of SNP's analyses are presented in Figures 2.2 and 2.3.

The flow dependent Minimum Critical Power Ratio ($MCPR_f$) limit and the results of SNP's analysis are presented in Figure 2.4. The flow dependent Linear Heat Generation Rate Factor ($LHGRFAC_f$) is presented in Figure 2.5. These flow dependent $LHGRFAC_f$ values and $MCPR_f$

limits have been established for Cycle 6 to support the "loop manual" mode of operation. These curves are based on conservative maximum core flow rates. Table 2.2 shows the coordinates used to construct Figures 2.1 through 2.5.

The implementation of the MCPR operating limit requires that the most restrictive operating limit be chosen from among the three MCPR curves based on exposure, flow, and power. Thus, the greater value of MCPR as given by $MCPR_e$, $MCPR_f$, or $MCPR_p$ is selected as the operating limit in accordance with the state point of operation (Figures 2.1, 2.2, and 2.4).

The results of previous analyses for the maximum system pressurization event are presented in References 2, 22, 24, and 25. The results show that the Grand Gulf Unit 1 safety valves have sufficient capacity and performance to protect the ASME Boiler and Pressure Vessel Code, Section III, Class I, maximum vessel pressure transient limit of 1375 psig during Cycle 6.

The fuel related Technical Specification limits for Cycle 6 operation are included in the reload analysis report (Reference 3).

TABLE 2.1 RESULTS OF ANALYSES

THERMAL LIMITS

Transient	Delta-CPR
Loss of Feedwater Heating (all conditions)	0.09
Control Rod Withdrawal Error (Reference 4)	
100% power	0.10
70% power (1 foot ganged rod withdrawals)	0.18
70% power (2 foot ganged rod withdrawals)	0.34
20% power	0.48

Feedwater Controller Failure Without Bypass Delta-CPR
(Limiting Fuel Type)

% Power/% Core Flow	EOC-30 EFPD	EOC	EOC+30 EFPD
104.2/108*	0.13	0.15	0.16
40/108	0.36		0.37

* 104.2% power/108% core flow is used for the Reload Licensing Analysis (RLA) conditions to conservatively bound 100% power/105% core flow.

TABLE 2.1 RESULTS OF ANALYSES (CONTINUED)

Load Rejection Without Bypass Delta-CPR
(Limiting Fuel Type)

% Power/% Core Flow	EOC-30 EFPD	EOC	EOC+30 EFPD
104.2/108*	0.14	0.16	0.18
40/108	0.16	----	0.17
40/108**	0.22	----	0.74
25/73.5**	0.79	----	0.76
25/40**	0.60	----	0.59

* 104.2% power/108% core flow is used for the Reload Licensing Analysis (RLA) conditions to conservatively bound 100% power/105% core flow.

** Direct scram on turbine trip disabled.

TABLE 2.2 OPERATING LIMIT COORDINATES

GRAND GULF UNIT 1 Cycle 6

MCPR(e) Limits
(Figure 2.1)

Core Average Exposure GWd/MTU	MCPR(e)
13.385 (BOC)	1.20
25.012 (EOC-30 EFPD)	1.20
25.012	1.25
25.831 (EOC)	1.25
26.650 (EOC+30 EFPD)	1.25

MCPR(p) Limits
(Figure 2.2)

Percent of Rated Core Power	MCPR(p)
100	1.20
70	1.24
70	1.41
40	1.49
40	1.85*
40	2.10**
25	2.05*
25	2.20**

* Core flow ≤ 50%.

** Core flow > 50%.

TABLE 2.2 OPERATING LIMIT COORDINATES (CONTINUED)

LHGRFAC(p) Limits
(Figure 2.3)

Percent of Rated Core Power	LHGRFAC(p)	
	8x8	9x9
100	1.00	1.00
70	1.00	1.00
40	0.69	0.75
25	0.69	0.75

MCPR(f) Limits
(Figure 2.4)

Percent of Rated Core Flow	MCPR(f)
20	1.28
30	1.28
65	1.20
105	1.20

TABLE 2.2 OPERATING LIMIT COORDINATES (CONTINUED)

LHGRFAC(f) Limits
(Figure 2.5)

Percent of Rated Core Flow	9x9-5 LHGRFAC(f)
110.0	1.000
100.0	1.000
90.0	1.000
80.0	1.000
70.0	1.000
68.5	1.000
60.0	0.954
50.0	0.900
40.0	0.846
30.0	0.792
20.0	0.792

Percent of Rated Core Flow	8x8 LHGRFAC(f)
110.0	1.000
100.0	1.000
84.3	1.000
80.0	0.977
70.0	0.928
60.0	0.880
50.0	0.837
40.0	0.794
30.0	0.752
20.0	0.752

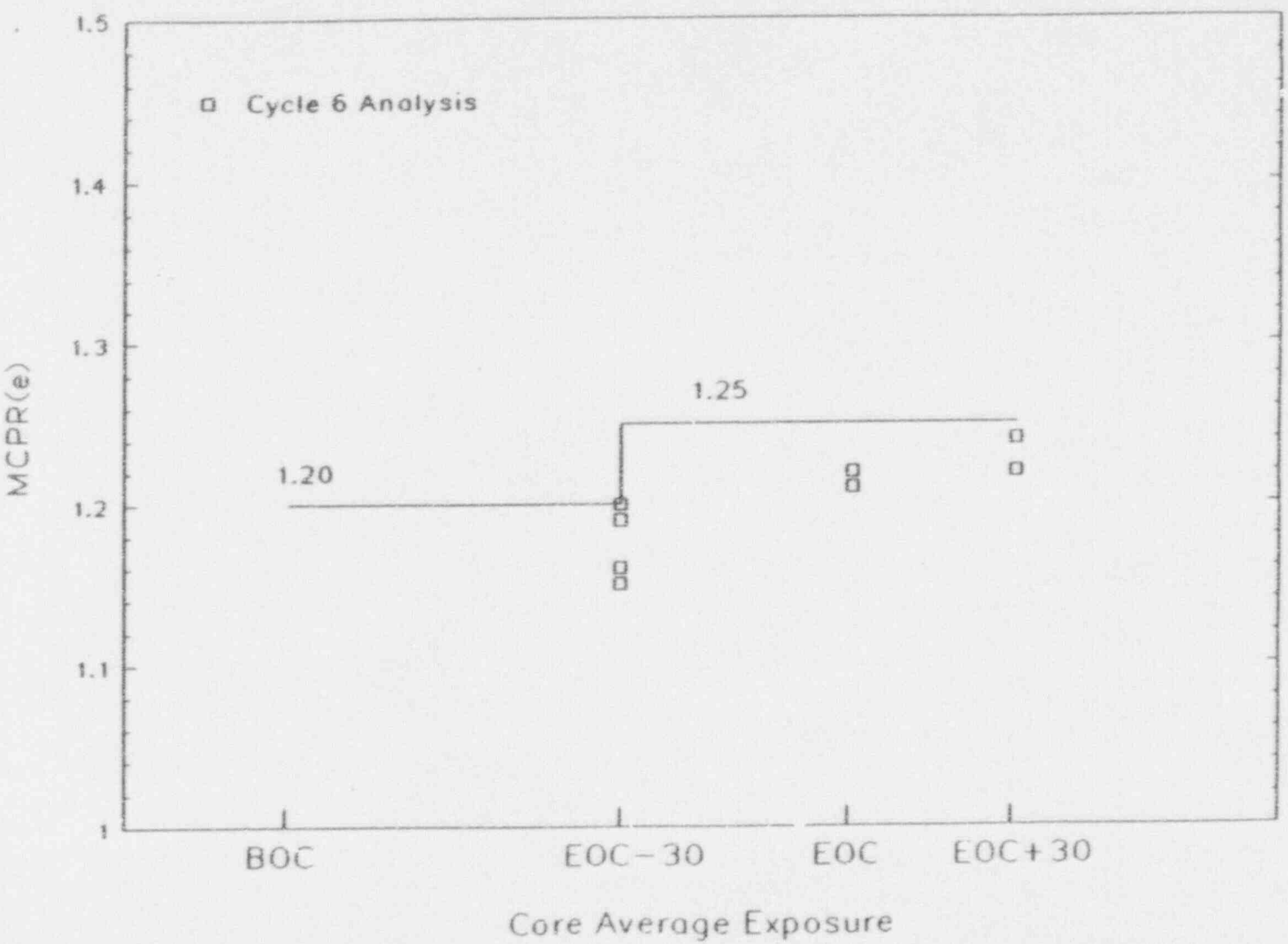

FIGURE 2.1 EXPOSURE DEPENDENT MCPR LIMITS FOR GRAND GULF UNIT 1 CYCLE 6

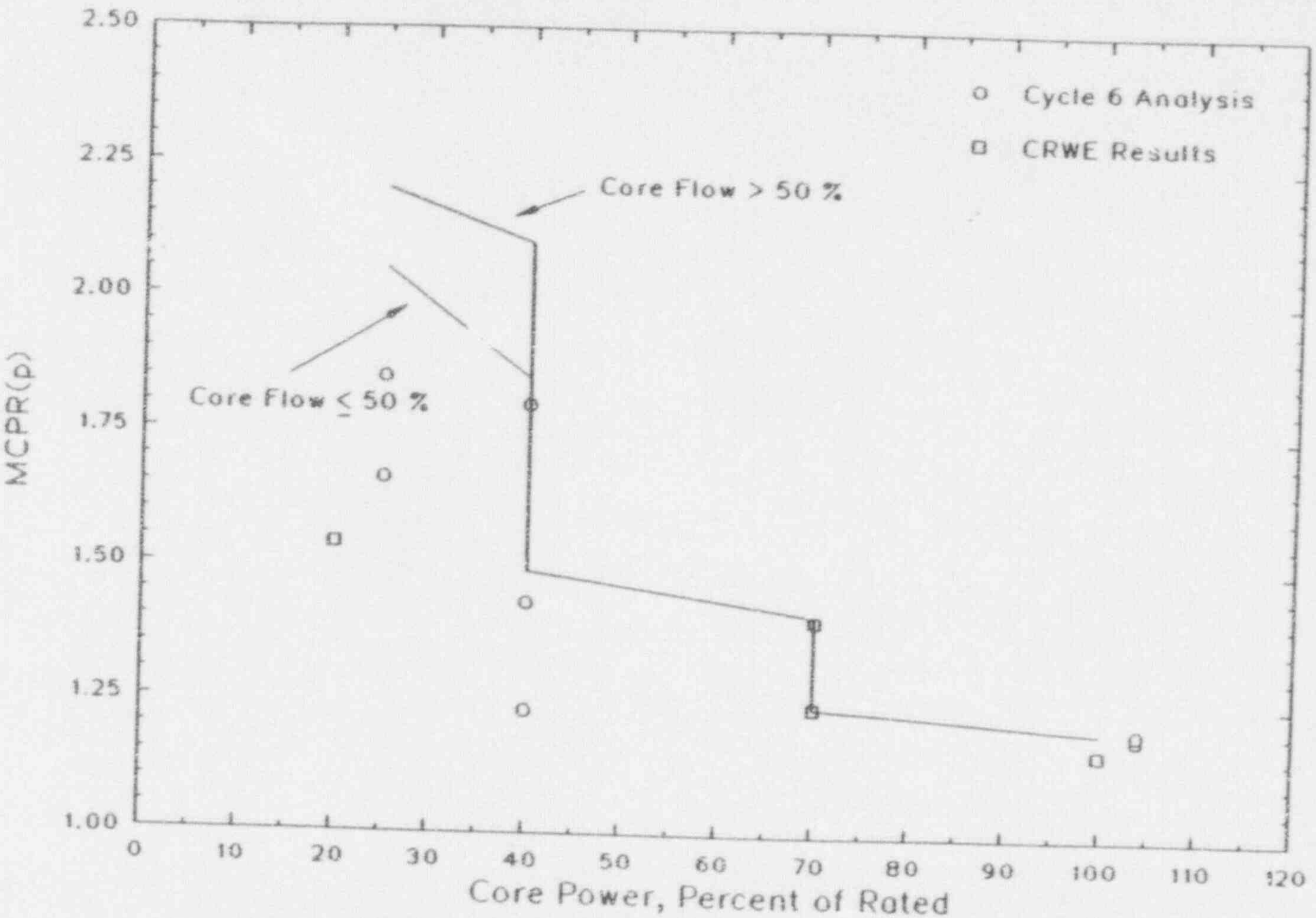

FIGURE 2.2 POWER DEPENDENT MCPR LIMITS FOR GRAND GULF UNIT 1 CYCLE 6

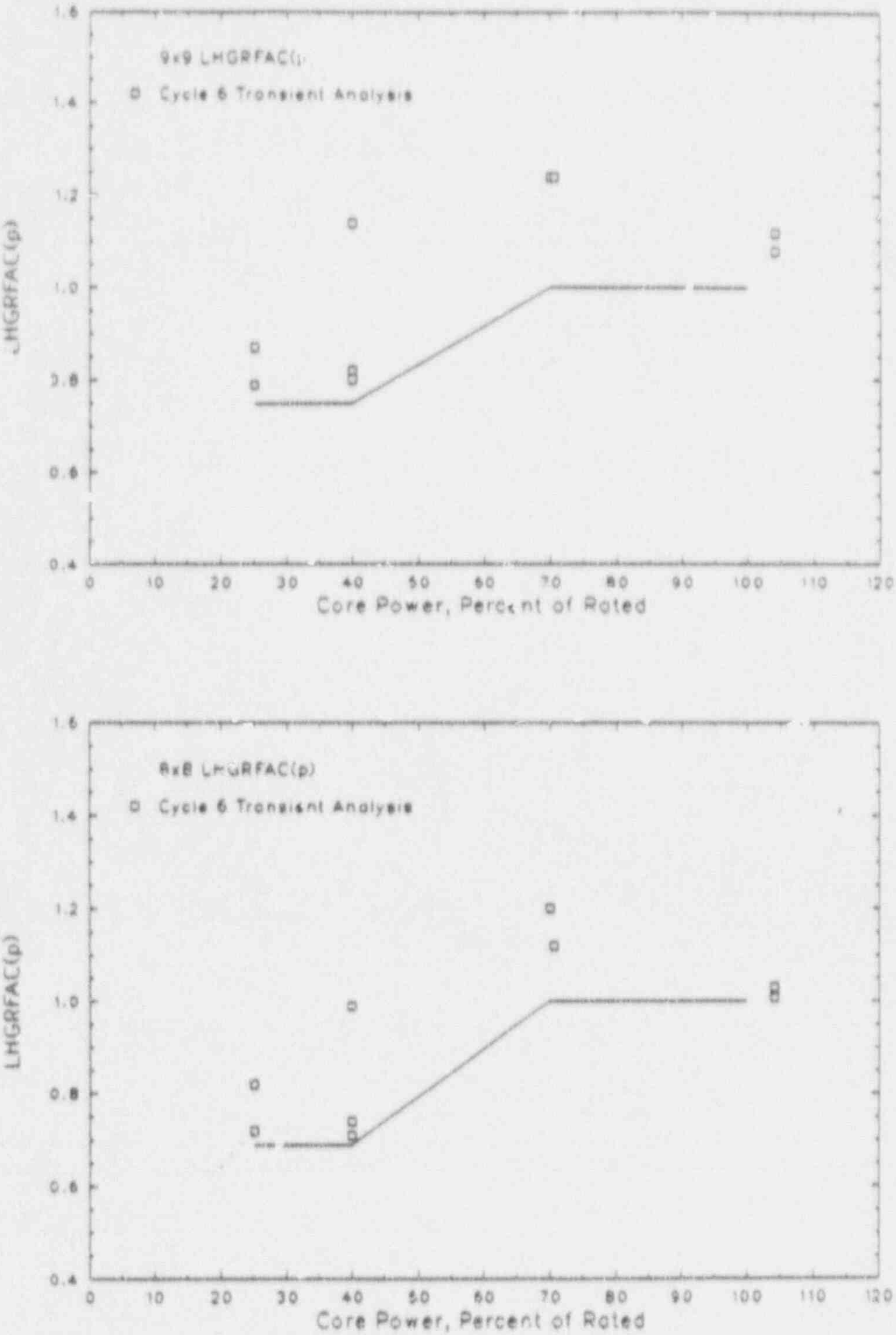

FIGURE 2.3 POWER DEPENDENT LHGRFAC VALUES FOR GRAND GULF UNIT 1 CYCLE 6

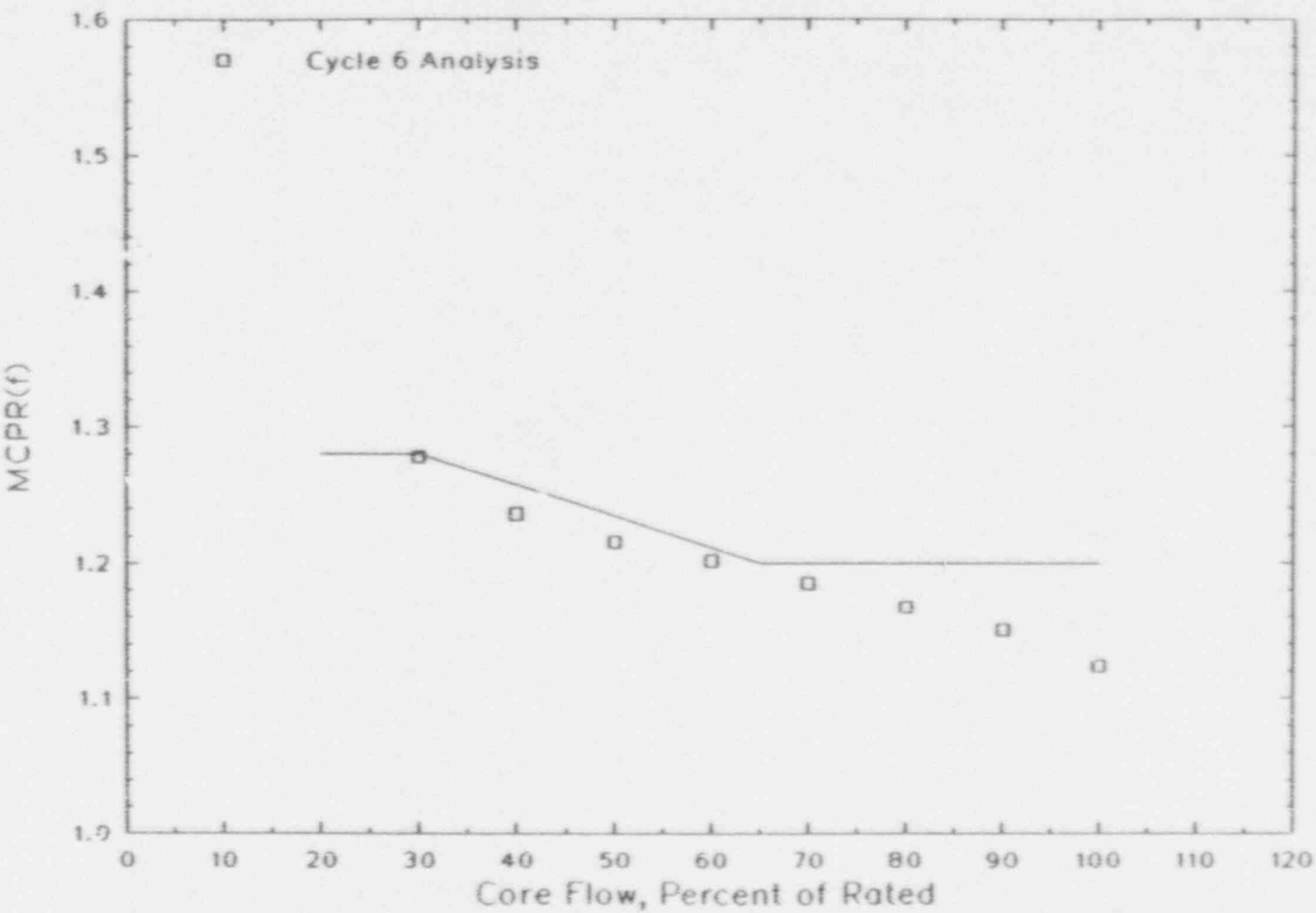

FIGURE 2.4 FLOW DEPENDENT MCPR LIMITS FOR GRAND GULF UNIT 1 CYCLE 6

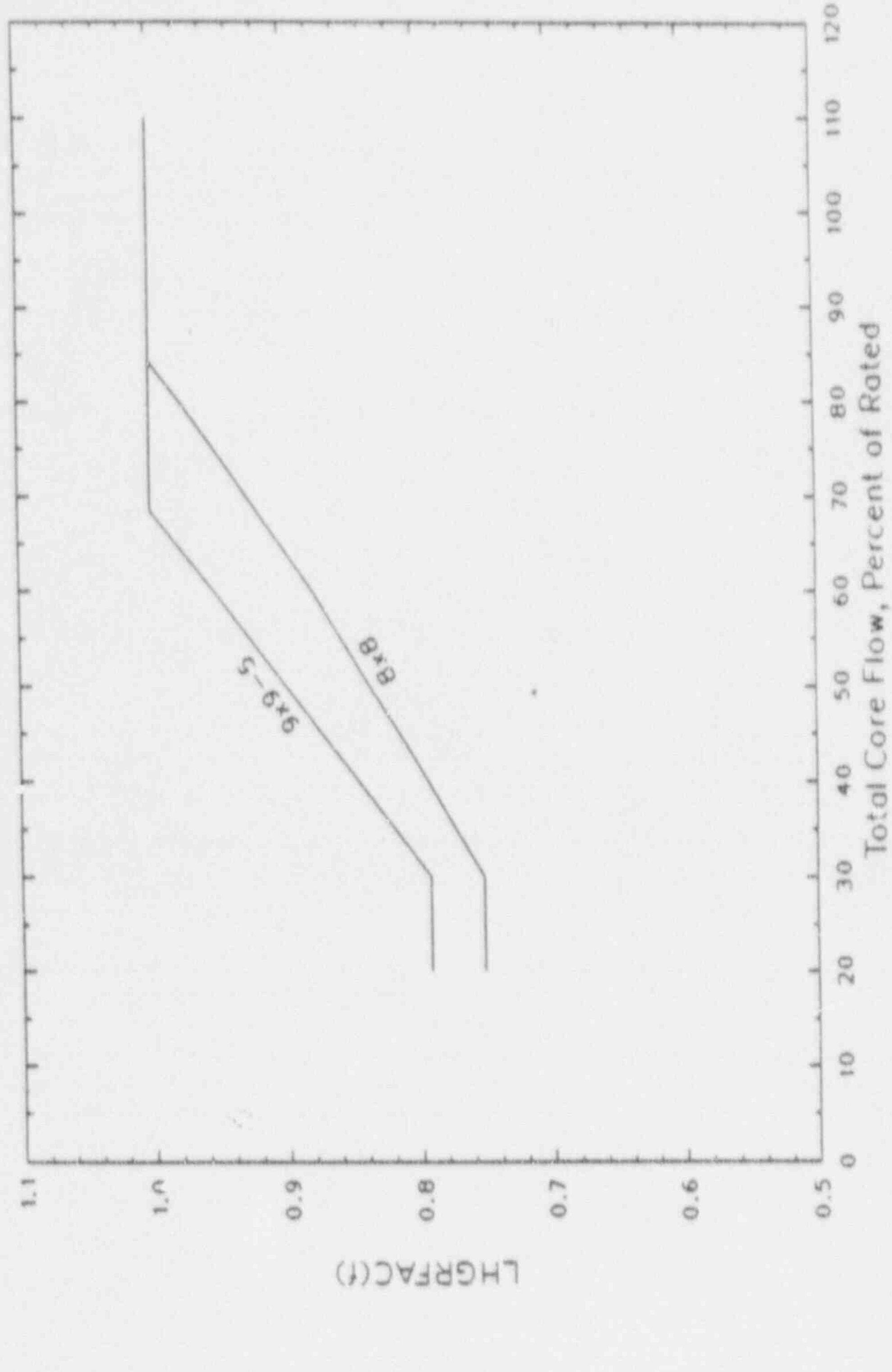

FIGURE 2.5 FLOW DEPENDENT LHGRFAC VALUE FOR GRAND GULF UNIT 1 CYCLE 6

3.0 THERMAL LIMITS ANALYSIS

3.1 Introduction

The scope of the thermal limits analysis includes system transients, localized core events, and safety limit analysis. Results of these analyses are used to establish power, flow, and exposure dependent MCPR limits and LHGRFAC values as appropriate.

COTRANSA2 (Reference 5), XCOBRA-T (Reference 6), XCOBRA (Reference 18), and MICROBURN-B (Reference 7) are the major codes used in the thermal limits analyses as described in SNP's THERMEX Methodology Report (Reference 8) and Neutronics Methodology Report (Reference 7). COTRANSA2 is a system transient simulation code which includes an axial one-dimensional neutronics model. XCOBRA-T is a transient thermal-hydraulic code used in the analysis of thermal margins of the limiting fuel assembly. MICROBURN-B is a three-dimensional steady state core simulation code which is used for Control Rod Withdrawal Error (CRWE), Loss of Feedwater Heating (LFWH), and flow excursion events ($LHGRFAC_f$). XCOBRA is a steady state thermal hydraulic code used in the analysis of slow flow excursion events ($MCPR_f$). The ANFB Critical Power Correlation (Reference 14) evaluates the thermal margins of the fuel assemblies. This correlation has been generically approved by the NRC (Reference 14).

3.2 System Transients

Thermal limits have been appropriately revised based upon SNP methods used in the Cycle 6 analysis. Figure 1.1 shows the four power/flow conditions that were analyzed in support of the Cycle 6 reload. System response for pressurization transients from these state points was analyzed for Cycle 6 using COTRANSA2. The Load Reject No Bypass (LRNB) pressurization transient analysis was performed at each of the four state points. The Feedwater Controller Failure (FWCF) analysis, without credit for bypass valve operation, was performed at 104.2%/108% and 40%/108%. ASME pressurization analyses were performed for Cycles 2, 3, 4, and 5 and were not repeated for Cycle 6. LFWH analyses were performed with MICROBURN-B for a large number of exposure points for Cycles 1 through 5 (Reference 22) as well as for Cycle 6. Analyses have been performed considering the SNP 9x9-5 fuel to assure that the power dependent limits supported by analyses for control rod withdrawal error remain applicable to

Grand Gulf Unit 1 Cycle 6. These analyses show less restrictive results or little change from the Cycle 5 analyses due to Cycle 6 changes, thus justifying that the less limiting transients not analyzed for Cycle 6 will continue to be protected. The pump seizure event was analyzed for single-loop operation for Cycle 6, the results are presented in Appendix A.

3.2.1 Design Basis

The LRNB and FWCF transients have been determined to be most limiting at end of full power capability when control rods are fully withdrawn from the core. Between BOC and EOC-30 EFPD, the CRWE transient is most limiting. From nominal EOC-30 EFPD to EOC+30 EFPD, the LRNB and FWCF transients are limiting. The delta-CPR calculated for EOC-30 EFPD, EOC, and EOC+30 EFPD is conservative for cases where control rods are partially inserted. The analysis for Grand Gulf Unit 1 with MEOD was performed using conservative analytical limits for trips and setpoints. Events initiated at core powers below 40% rated were analyzed with the direct scram due to turbine control and stop valve fast closure disallowed, and with the recirculation pump high to low speed transfer disabled. Recirculation pump trip on high dome pressure was enabled for events initiated at core powers below 40% rated.

3.2.2 Anticipated Transients

SNP's transient methodology report for jet pump BWRs (Reference 19) considered eight categories of anticipated transients. The most limiting transients were evaluated at various power/flow points within MEOD to verify the power dependent thermal margin for Grand Gulf Unit 1 Cycle 6. The limiting transients analyzed for Grand Gulf Unit 1 Cycle 6 were:

- Loss of Feedwater Heating
- Load Rejection No Bypass
- Feedwater Controller Failure No Bypass

Other transients are inherently non-limiting or bounded by one of the above as shown in the NSSS vendor MEOD analyses for Cycle 1 and the SNP Grand Gulf Unit 1 Cycle 2 analyses. Control rod withdrawal error is an exception in that it has been analyzed generically.

3.2.2.1 Loss Of Feedwater Heating

Analysis of the loss of feedwater heating event was performed to reflect reactor operation over the MEOD operating power versus flow map and conditions anticipated during actual Grand Gulf reactor operation.

Calculations performed for Cycles 1 through 5 assumed a conservative reduction of 100°F in the feedwater temperature. Results for Cycles 1 through 5 are provided in Table 3.1 of Reference 22. Table 3.1 provides the conditions for the cases analyzed in Cycle 6 in terms of cycle exposure, core power, and core flow. The initial and final MCPR values are presented for each case.

Analysis of the data from previous cycles revealed a strong correlation between the initial and final MCPR. A least squares fit of these data resulted in a linear relationship such that:

$$MCPR(initial) = -0.04974 + 1.1021 * MCPR(final)$$

In order to conservatively bound all of the calculated data, the largest deviation between the calculated and fitted results were applied to the least squares fit such that the LFWH MCPR operating limit is defined by:

$$OLMCPR(LFWH) = -0.02386 + 1.1021 * SLMCPR$$

This bounding relationship and the Cycle 6 data are presented in Figure 3.1. Substituting the SLMCPR of 1.06, the MCPR operating limit for the LFWH event for all operating conditions analyzed is 1.15.

3.2.2.2 Load Rejection No Bypass

The Load Rejection No Bypass (LRNB) event is the most limiting of the class of transients characterized by rapid vessel pressurization for Grand Gulf Unit 1. The load rejection causes a fast closure of the turbine control valves. The resulting compression wave travels through the steam lines into the vessel and creates the rapid pressurization condition. A reactor scram and a recirculation pump transfer from high to low speed are initiated by fast closure of the control valves. Condenser bypass flow, which can mitigate the pressurization effect, is not credited. The excursion of the core power due to void collapse is primarily terminated by reactor scram and void growth due to the recirculation pump high to low speed transfer.

Figures 3.2, 3.3, and 3.4 present the response of various reactor and plant parameters to the LRNB event initiated at the Reload Licensing Analysis condition (104.2% power/108% core flow). The MCPR operating limit of 1.20 is bounding for all exposures up to EOC-30 EFPD. The MCPR operating limit of 1.25 is bounding for all exposures between EOC-30 and EOC+30 EFPD conditions. Table 2.1 lists the delta-CPRs for this transient at the power/flow conditions and exposure conditions considered.

3.2.2.3 Feedwater Controller Failure

The failure of the feedwater controller to maximum demand (FWCF) is the most limiting of the vessel inventory increase transients. Failure of the feedwater control system to maximum demand would result in an increase in the coolant level in the reactor vessel. Increased feedwater flow results in lower temperatures at the core inlet, which in turn cause an increase in core power level. If the feedwater flow stabilizes at the increased value, the core power will stabilize at a new, higher value. If the flow increase continues, the water level in the downcomer will eventually reach the high level setpoint, at which time the turbine stop valve is closed to avoid damage to the turbine from excessive liquid inventory in the steamline. The high water level trip also initiates reactor scram, and subsequent turbine trip leads to recirculation pump high to low speed transfer. The core power excursion is terminated by the same mechanisms that end the LRNB transient.

Figures 3.5, 3.6, and 3.7 present the response of various reactor and plant parameters to the FWCF without bypass event initiated at the Reload Licensed Analysis condition (104.2% power/108% core flow). The delta-CPR for this event was calculated to be 0.15 at EOC. This delta-CPR is bounded by the LRNB delta-CPR. At EOC-30 and EOC+30 EFPD the delta-CPR for this event is also bounded by the LRNB. The cases of FWCF with bypass and with feedwater heaters out of service (-100 °F) were analyzed in previous cycles and shown to be bounded by FWCF without bypass case.

3.2.2.4 Control Rod Withdrawal Error

Reference 4 documents SNP's generic CRWE analysis for Grand Gulf Unit 1 operation within the MEOD. The applicability of these analyses was confirmed by performing CRWE analyses with MICROBURN-B using SNP's ANFB critical power correlation. Based on Reference 4 operating conditions and analytical procedures, one and two foot CRWE events were simulated. Designs using 9x9-5 fuel were also analyzed (Reference 22). The results of these analyses were statistically combined to produce a 95/95 upper limit for various power levels. This upper limit is bounded by the generic analysis results. Figure 2.2 shows the operating limit curve for protecting the Cycle 6 fuel under CRWE conditions based on SNP's generic CRWE analysis and the Cycle 6 MCPR safety limit of 1.06.

3.2.2.5 Power-Dependent LHGR Limit

Transient analyses have been performed to define appropriate multipliers on the fuel design limit LHGR for part power operation. The purpose of these multipliers is to protect fuel from failure due to centerline melt and exceeding the 1% plastic strain mechanical performance design criteria during off-rated condition transient events. Analyses were performed for the Load Rejection No Bypass (LRNB) and Feedwater Controller Failure (FWCF) pressurization event transients and the Control Rod Withdrawal Error event which is a localized event. Analyses performed for Cycle 2 showed the LRNB and FWCF transients to be limiting relative to MCPR and LHGR increases. CRWE analyses performed at various off-rated conditions on the power/flow map gave results which were less restrictive than for the LRNB and FWCF events. The LRNB and FWCF transients were evaluated for Cycle 6 considering a variety of exposure and operating conditions. The results of these analyses are provided in Figure 2.3 and demonstrate adequate margin to the operating limit. Separate limits are established for SNP 8x8 and 9x9-5 fuel types based upon the appropriate transient LHGR limit for each fuel type.

3.3 Flow Excursion Analysis

The flow excursion transient is analyzed to determine the flow dependent thermal limits and values ($MCPR_f$ and $LHGRFAC_f$). This transient is analyzed by assuming a failure of the recirculation flow control system such that the recirculation flow increases slowly to the physical maximum attainable by the equipment. The mode of operation analyzed for Grand Gulf Unit 1 Cycle 6 is "loop manual" only. This mode of operation corresponds to a single recirculation loop flow excursion event.

The results of the flow excursion transient analyses were used to establish new flow dependent thermal limits of $MCPR_f$. For these analyses the change in critical power along the flow ascension path was calculated with XCOBRA (Reference 18). Peaking factors were selected such that the bundle with the least margin would reach the safety limit MCPR of 1.06 at the maximum achievable flow. Figure 2.4 presents the $MCPR_f$ limit for maximum achievable core flow, conservatively assuming that the recirculation system equipment is capable of 110% of rated flow on the limiting rod line. For flow rates less than 30% rated flow, the recirculation system operates at low speed restricting the maximum possible flow. Because of this restriction, the $MCPR_f$ curve conservatively remains fixed between 20% flow and 30% flow.

The Cycle 6 $LHGRFAC_f$ analysis was performed with the CASMO-3G/MICROBURN-B neutronic codes assuming a single pump runup flow excursion. The analysis assumes that the recirculation flow increases slowly along the limiting rod line (Reference 2) with a maximum core flow capacity of 110% of rated. A series of flow excursion analyses were performed starting from different initial power/flow-conditions. Variations in the cycle exposure and control rod patterns were also considered. The final conditions are conservatively determined based on the maximum attainable core flow rate. Xenon is conservatively assumed to remain constant during the event. The operating limits were established to bound the limiting results and are shown in Figure 2.5. Separate limits are established for CNP 8x8 and 9x9-5 fuel types based upon the appropriate transient LHGR limit for each fuel type. Because of restrictions in flow rates attainable for operation with core flows less than 30% of rated, the $LHGRFAC_f$ conservatively remains constant for core flow rates between 20% and 30%.

3.4 Safety Limit

The safety limit MCPR is defined as the minimum value of the critical power ratio at which the fuel could be operated, with the expected number of rods in boiling transition not exceeding 0.1% of the fuel rods in the core. The safety limit is the minimum critical power ratio which would be permitted to occur during the limiting anticipated operational occurrence. The safety limit MCPR for all fuel types in Grand Gulf Unit 1 Cycle 6 operation was calculated to be 1.06 using the methodology presented in References 9 and 11. The determination of the safety limit explicitly includes the effects of channel bow and relies on the following assumptions:

1. Cycle 6 will not contain channels used for more than one fuel bundle lifetime.
2. The channel exposure at discharge will not exceed 40,000 MWd/MTU based on the fuel bundle average exposure.
3. The Cycle 6 core will contain GE and Cartech supplied channels.
4. The limiting module contains a conservative exposure configuration.

The input parameter values for uncertainties used in the safety limit MCPR analysis are unchanged from the Cycle 2 analysis presented in Reference 2 except for the uncertainties associated with the ANFB correlation, its implementation in the safety limit evaluation, channel bow, and the uncertainties appropriate for CASMO/MICROBURN analysis. The limiting local power distribution used to determine the safety limit MCPR is shown in Figure 3.8. The effects of channel bow were modeled in the safety limit evaluation.

3.5 Summary of Results

The results of the Grand Gulf Unit 1 Cycle 6 thermal limits analysis show a Cycle 6 safety limit MCPR of 1.06 and a MCPR operating limit of 1.20 at rated conditions for exposures below EOC-30 EFPD. A MCPR operating limit of 1.25 at rated conditions is shown from EOC-30 to EOC+30 EFPD. These exposure dependent limits are shown in Figure 2.1. The MCPR operating limit considers the effects of exposure ($MCPR_e$), flow ($MCPR_f$), and power ($MCPR_p$). The operating limit of interest is the larger of the three values for a given reactor operating condition.

3.5.1 Power Dependent Thermal Limits and Values

The power dependent MCPR limit ($MCPR_p$) protects against exceeding the safety limit MCPR during anticipated operational occurrences from off-rated conditions. The $MCPR_p$ limit bounds the sum of the delta-CPR for the limiting event and the calculated safety limit MCPR.

The power dependent LHGRFAC ($LHGRFAC_p$) is used to protect against both fuel melting and 1% clad strain during anticipated system transients from off-rated conditions. The conservative LHGR values for protection against fuel failure during anticipated operational occurrences are given in References 10 and 13. The results are presented in a fractional form for application to the LHGR operating limit. The flow dependence of the $LHGRFAC_p$ at low power has been conservatively removed.

The $MCPR_p$ limits and $LHGRFAC_p$ values for Cycle 6 are shown in Figures 2.2 and 2.3, respectively. Results from the Cycle 6 transient analyses and the SNP generic CRWE analyses establish the $MCPR_p$ operating limit for Cycle 6. The Cycle 6 $LHGRFAC_p$ values establish the applicable operating limits for SNP 8x8 and 9x9-5 fuel.

3.5.2 Flow Dependent Thermal Limits and Values

The flow dependent MCPR limit ($MCPR_f$) protects against exceeding the safety limit MCPR for slow flow excursion events. The results of the $MCPR_f$ analysis for Grand Gulf Unit 1 Cycle 6 are presented in Figure 2.4. The flow dependent LHGRFAC ($LHGRFAC_f$) protects against both fuel melting and 1% clad strain. The $LHGRFAC_f$ values for SNP 8x8 and 9x9-5 fuel to be used in Cycle 6 are presented in Figure 2.5.

3.5.3 Exposure Dependent Thermal Limits

The exposure dependent MCPR limit ($MCPR_e$) protects against exceeding the safety limit MCPR during the operation of the core. The results of the exposure dependent analysis for Grand Gulf Unit 1 Cycle 6 are presented in Figure 2.1.

TABLE 3.1 GRAND GULF UNIT 1 CYCLE 6 LFWH DATA SUMMARY

	Initial State			Final State		
Cycle Exposure (GWd/MT)	Total Core Power (MWt)	Total Core Flow (Mlb/hr)	Core Minimum CPR	Total Core Power (MWt)	Total Core Flow (Mlb/hr)	Core Minimum CPR
0.00	3833	106.88	1.472	4333	106.88	1.385
1.00	3833	102.38	1.460	4332	102.38	1.376
2.00	3833	103.50	1.476	4335	103.50	1.382
3.00	3833	96.75	1.445	4336	96.75	1.352
4.00	3833	101.25	1.427	4332	101.25	1.346
5.00	3833	104.63	1.430	4333	104.63	1.342
6.00	3833	99.00	1.397	4324	99.00	1.301
7.00	3833	100.13	1.386	4328	100.13	1.298
8.00	3833	99.00	1.316	4314	99.00	1.235
9.00	3833	100.13	1.328	4296	100.13	1.251
10.00	3833	105.75	1.336	4283	105.75	1.265
11.00	3833	105.75	1.369	4272	105.75	1.296
12.00	3833	103.50	1.382	4260	103.50	1.314
12.45	3833	112.50	1.409	4266	112.50	1.338
13.27	3833	112.50	1.423	4261	112.50	1.353

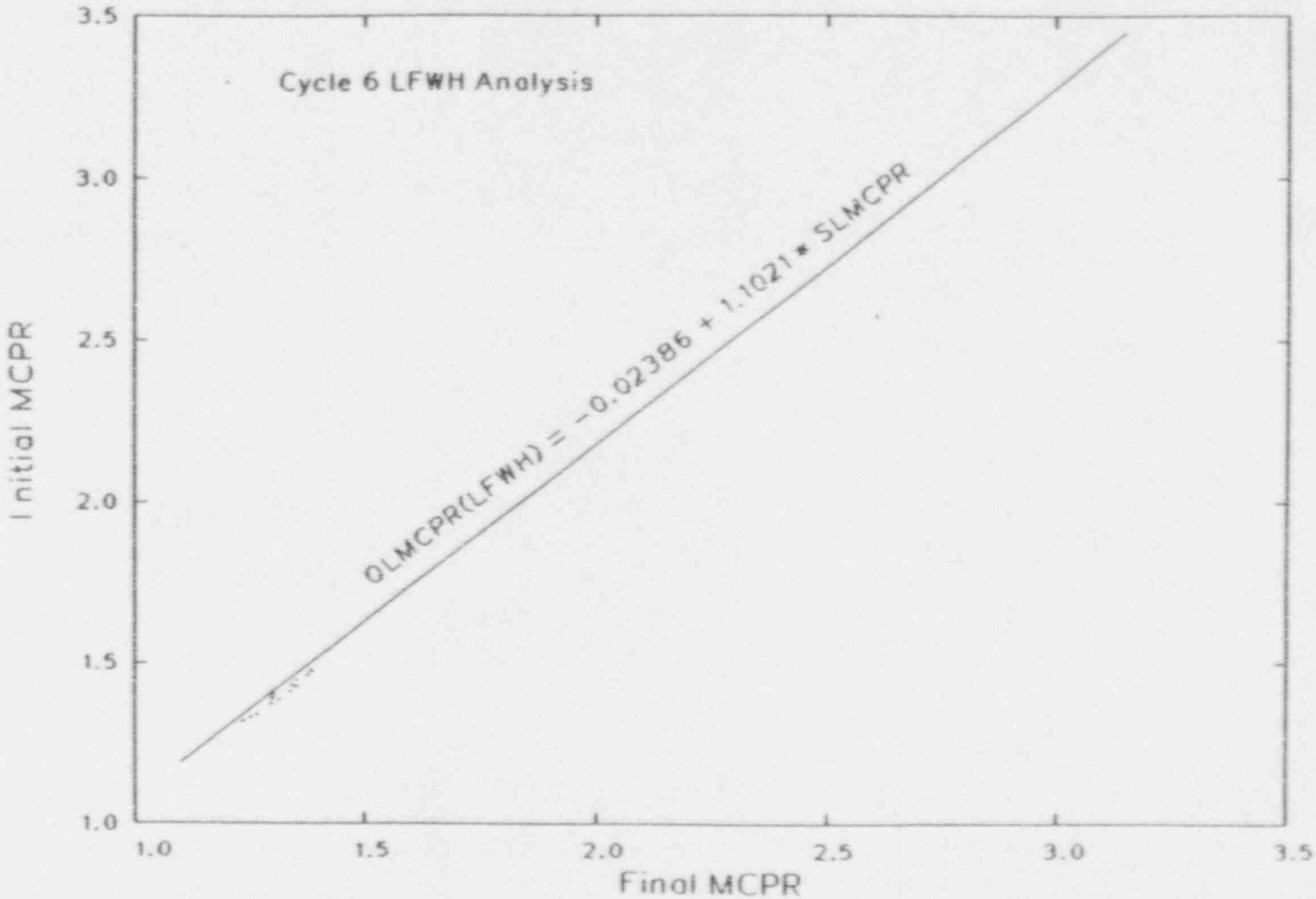

FIGURE 3.1 ANALYSIS OF LFWH INITIAL MCPR VERSUS FINAL MCPR

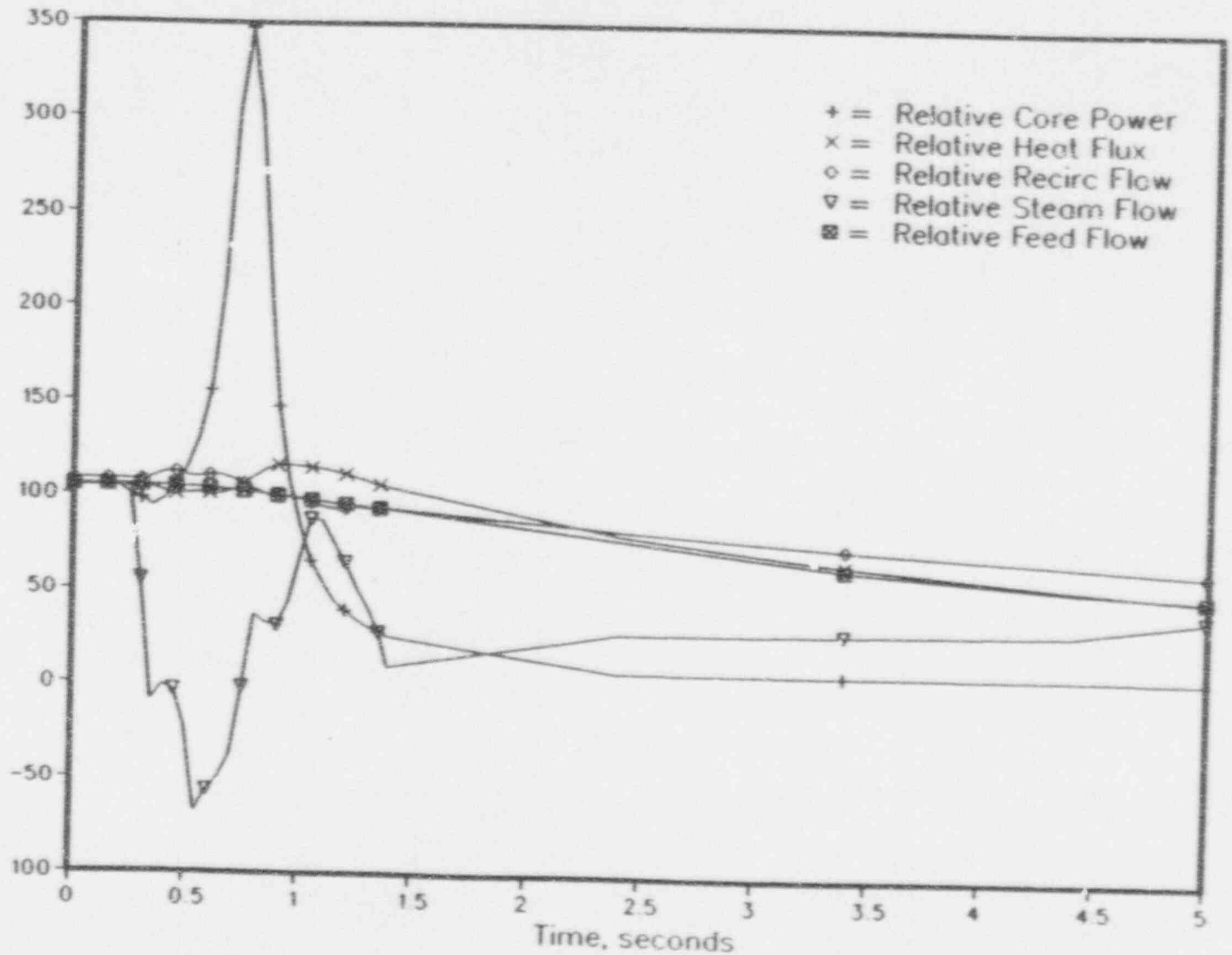

FIGURE 3.2 LOAD REJECTION WITHOUT BYPASS (POWER AND FLOWS)

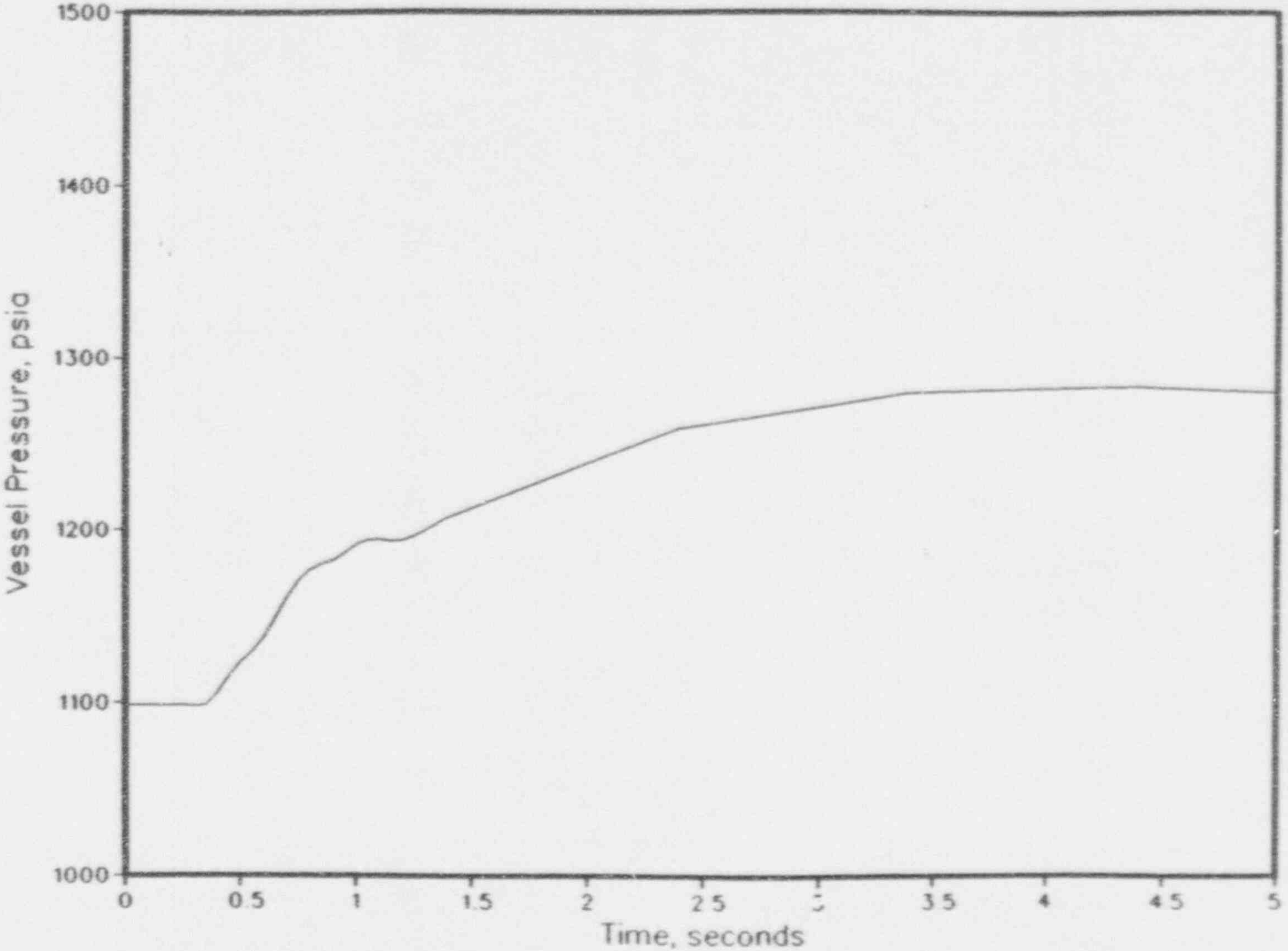

FIGURE 3.3 LOAD REJECTION WITHOUT BYPASS (VESSEL PRESSURE)

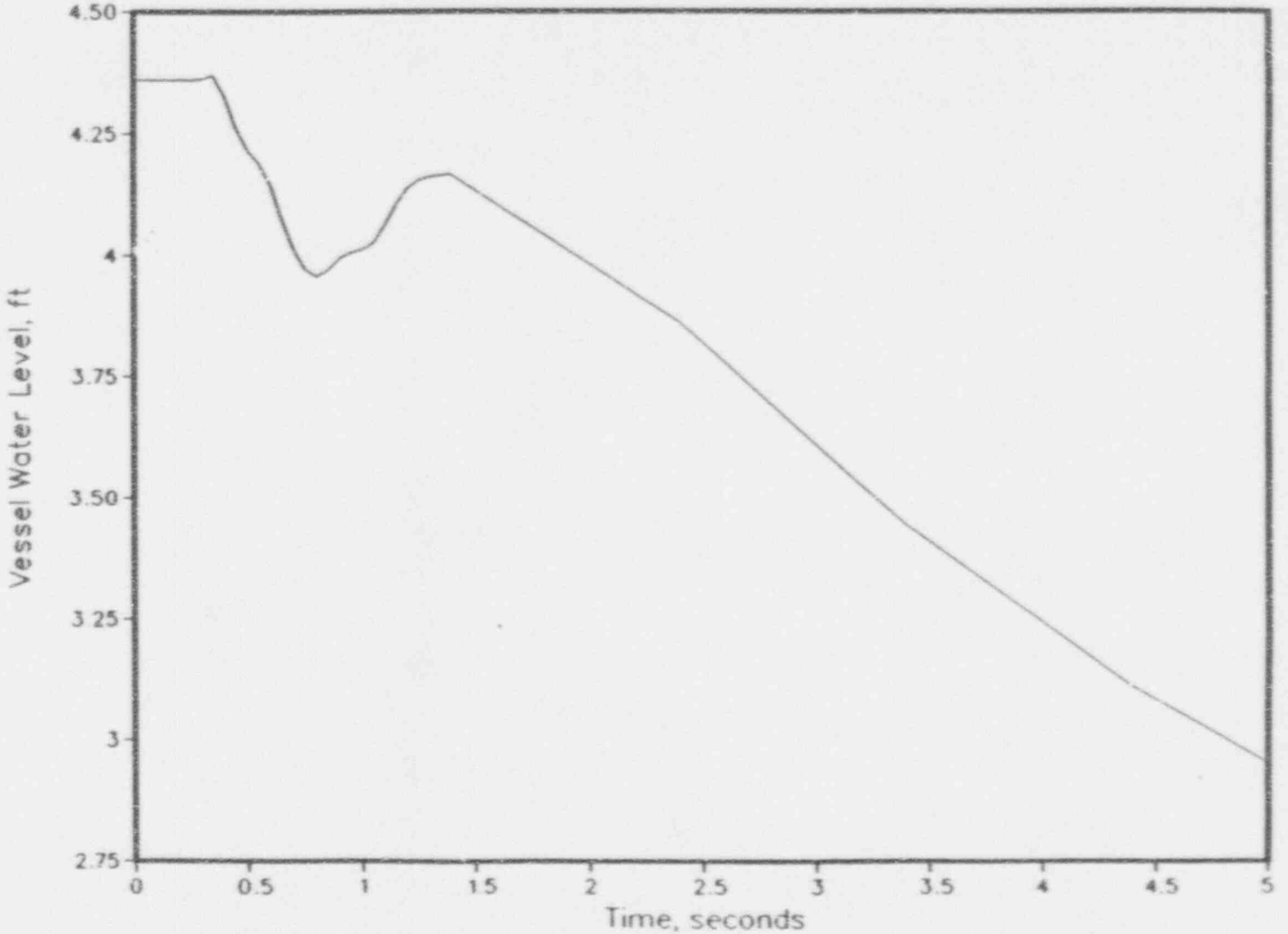

FIGURE 3.4 LOAD REJECTION WITHOUT BYPASS (WATER LEVEL ABOVE SEPARATOR SKIRT)

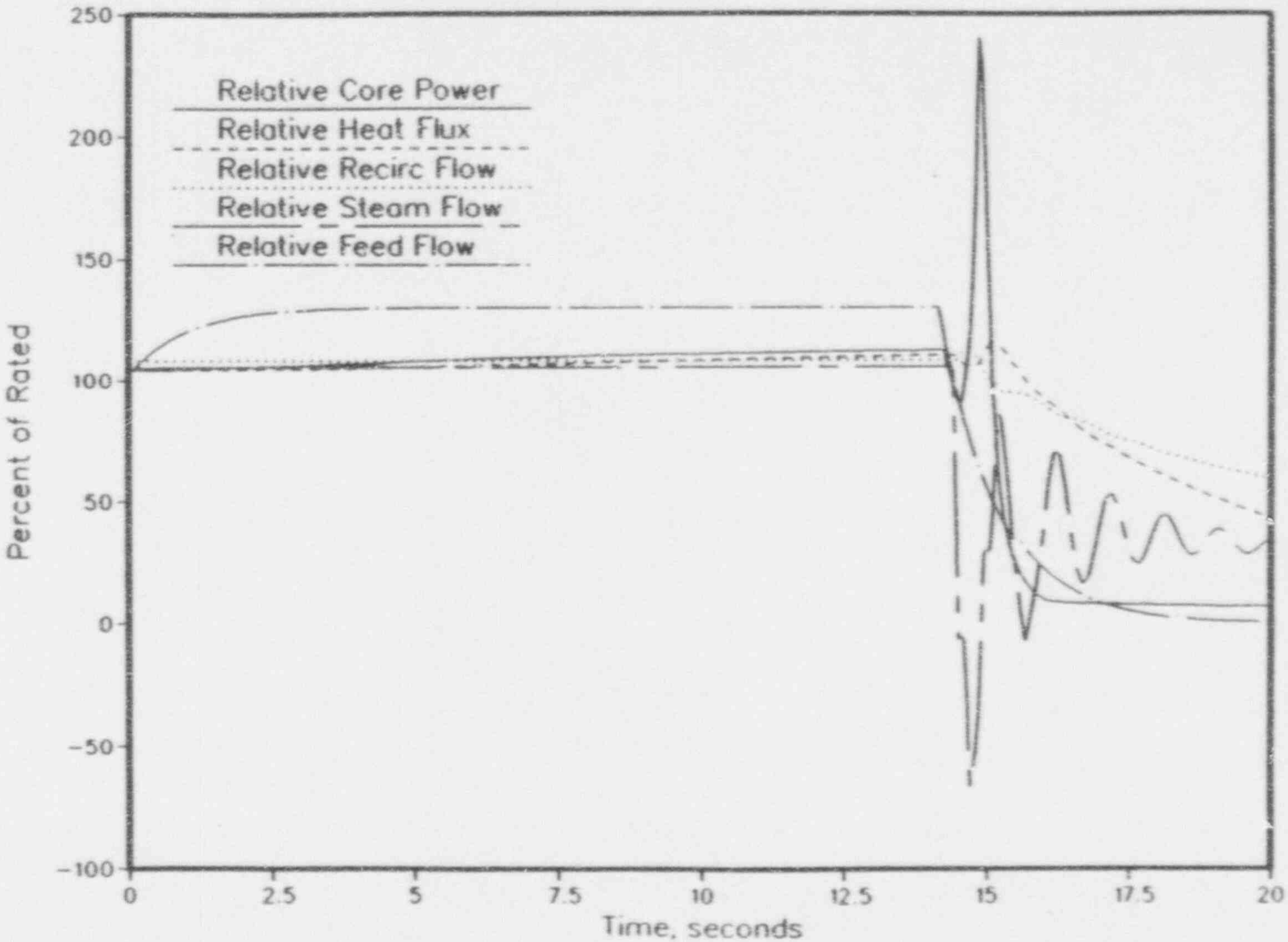

FIGURE 3.5 FEEDWATER CONTROLLER FAILURE (POWER AND FLOWS)

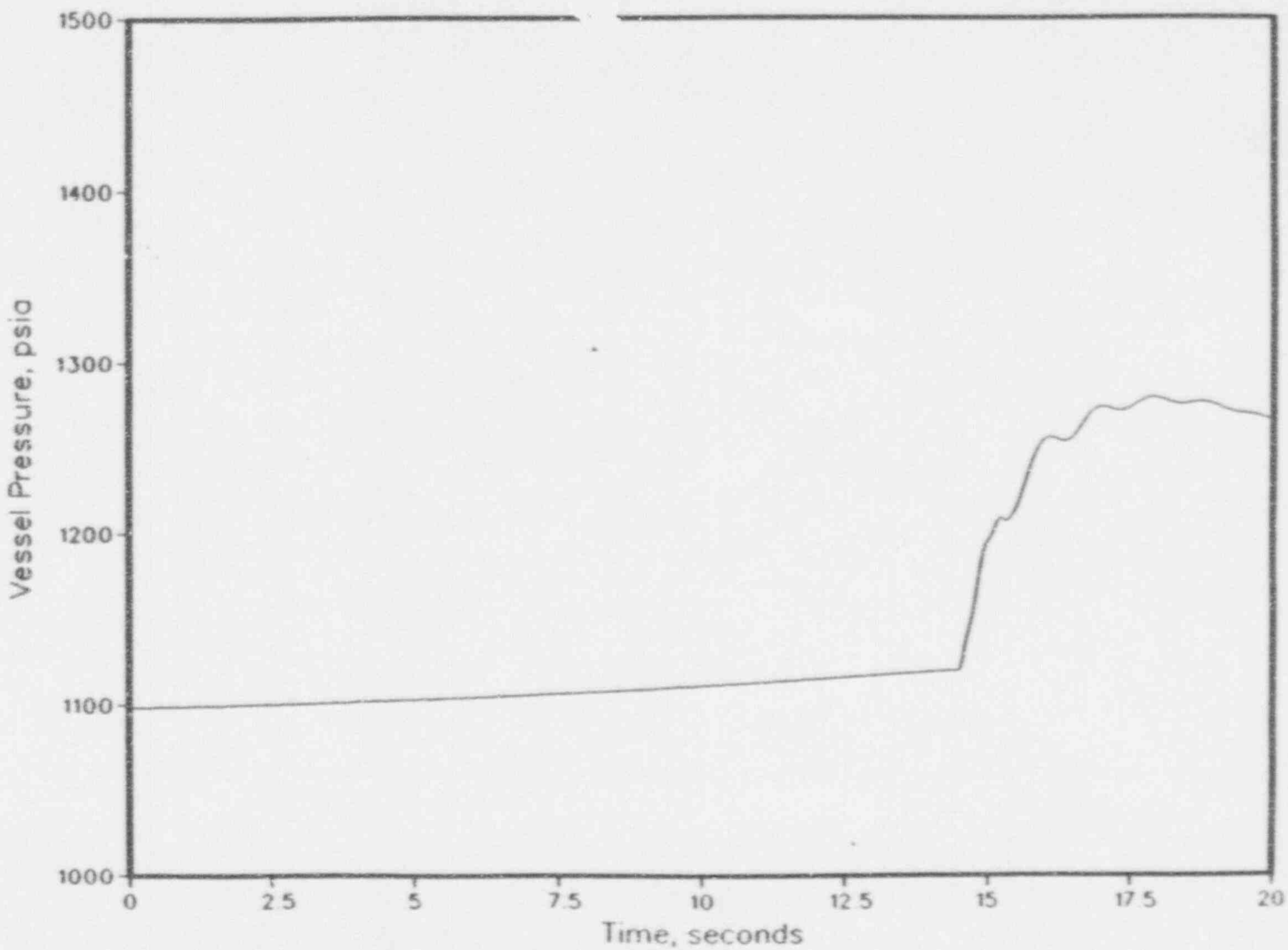

FIGURE 3.6 FEEDWATER CONTROLLER FAILURE (DOME PRESSURE)

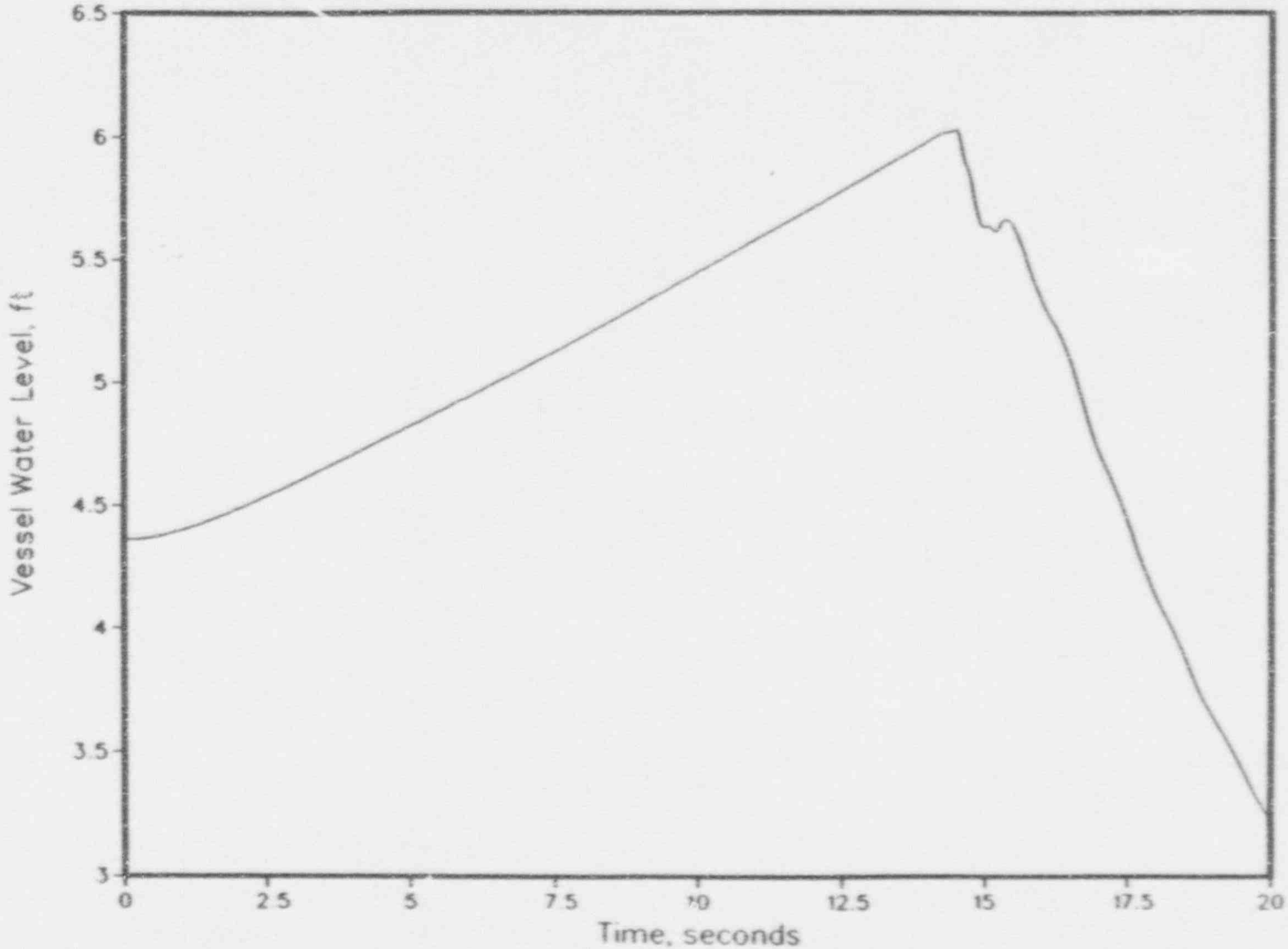

FIGURE 3.7 FEEDWATER CONTROLLER FAILURE (WATER LEVEL ABOVE SEPARATOR SKIRT)

CONTROL ROD

CONTROL ROD									
	0.986	1.025	1.018	1.030	1.063	1.030	1.018	1.025	0.986
	1.025	0.967	1.047	0.989	0.814	0.989	1.047	0.966	1.025
	1.018	1.047	1.028	0.970	0.994	0.968	1.027	1.047	1.019
	1.030	0.989	0.970	0.897	0.000	1.050	0.970	0.990	1.031
	1.063	0.814	0.994	0.000	0.000	0.000	0.999	0.814	1.064
	1.030	0.989	0.968	1.050	0.000	0.889	0.982	0.993	1.032
	1.018	1.047	1.027	0.970	0.999	0.982	1.035	1.051	1.020
	1.025	0.966	1.047	0.990	0.814	0.993	1.051	0.967	1.027
	0.986	1.025	1.019	1.031	1.064	1.032	1.020	1.027	0.987

FIGURE 3.8 GRAND GULF UNIT 1 CYCLE 6 SAFETY LIMIT DESIGN BASIS LOCAL POWER DISTRIBUTION

4.0 MAXIMUM OVERPRESSURIZATION

Maximum system pressure has been calculated for the containment isolation event (rapid closure of all main steam isolation valves) with an adverse scenario as specified in the ASME Pressure Vessel Code for Cycles 2 through 5 (References 2, 22, 24, and 25). These analyses demonstrate that the Grand Gulf Unit 1 safety valves have sufficient capacity and performance to prevent pressure from reaching the established transient pressure limit of 110% of design pressure (1.1 x 1250 = 1375 psig).

4.1 Design Basis

During the transient, the most critical active component (direct scram on MSIV closure) was assumed to fail. The event was terminated by the high flux scram. Credit was taken for actuation of only 13 of the 20 safety/relief valves: 6 in the relief mode and 7 in the safety mode. The safety valve analysis setpoints for these calculations included a conservative 6% tolerance.

4.2 Maximum Pressurization Transients

Scoping analyses described in Reference 19 found the closure of all main steam isolation valves (MSIVs) without direct scram to be limiting. The MSIV closure was found to be limiting when all transients are evaluated on the same basis (without direct scram) because of the smaller steam line volume associated with MSIV closure. Though the closure rate of the MSIVs is substantially slower than turbine stop or control valves, the compressibility of the additional fluid in the steam lines associated with a turbine isolation causes these faster closures to be less severe. Once the containment is isolated, the subsequent core power production must be absorbed in a smaller volume compared to that of a turbine isolation resulting in higher vessel pressures.

4.3 Results

The maximum vessel pressures at the most limiting power/flow point for ti · previous cycles analyses demonstrate that the maximum vessel pressure varies over a very narrow range (1271 psig to 1298 psig) independent of fuel and core design and that sufficient margin, more than 75 psid, is available to accommodate the minor changes represented by the Cycle 6 reload.

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20. Not used.

21. Not used.

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23. "Grand Gulf Unit 1 Cycle 6 Single Loop Operation LOCA Analysis Report," EMF-91-172, Siemens Nuclear Power Corporation, Richland, WA, August 1991.

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APPENDIX A SINGLE-LOOP OPERATION

Analyses have been provided by the NSSS vendor that demonstrate the safety of plant operation with a single recirculation loop out of service for an extended period of time. These analyses confirm that during single-loop operation, the plant cannot reach the normal bundle power levels and nodal power levels that are possible when both recirculation systems are in operation. The physical interdependence between core power and recirculation flow rate inherently limits the core to less than rated power. Because the SNP 9x9-5 fuel was designed to be compatible with the co-resident 8x8 fuel in thermal hydraulic, nuclear, and mechanical design performance, and because the SNP methodology has given results which are consistent with those of the previous analyses for two-loop operation, the analyses performed by the NSSS supplier for single-loop operation are also applicable to single-loop operation with fuel and analyses provided by SNP.

A.1 PUMP SEIZURE ACCIDENT

The pump seizure is a postulated accident where the operating recirculation pump suddenly stops rotating. This causes a rapid decrease in core flow, a decrease in the rate at which heat can be transferred from the fuel rods and a decrease in the critical power ratio. COTRANSA2 and XCOBRA-T are used to calculate the MCPR for SNP fuel during a pump seizure from single-loop operation.

COTRANSA2 was used to simulate system response to a pump seizure in single-loop operation at the power flow point of 70.6% rated power and 54.1% rated flow. The operating recirculation pump rotor was stopped quickly causing a sudden decrease in the active jet pump drive flow. During the event, the inactive jet pump diffuser flow went from negative flow to positive flow. Figures A.1, A.2, and A.3 show the graphical representation of important system parameters during the accident.

Thermal hydraulic analysis using SNP safety limit methodology has shown that the two-loop $MCPR_p$ limit provides the required protection below 70% of rated core power such that any postulated fuel failures would not result in exceeding a small fraction (<10%) of the 10CFR100 requirements.

A.2 MCPR SAFETY LIMIT

For single-loop operation, SNP has determined that a safety limit of 1.07 provides sufficient protection to account for increased TIP uncertainties and increased flow measurement uncertainties associated with single-loop operation. SNP has evaluated the effects of these uncertainties using SNP safety limit methodology and determined that augmenting the two-loop safety limit MCPR by 0.01 is appropriate for SNP fuel during single-loop operation for Cycle 6.

A.3 FLOW DEPENDENT AND POWER DEPENDENT THERMAL LIMITS

It is appropriate to use the reduced flow and power two-loop operating MCPR and LHGRFAC limits for single-loop operations. The reduced flow MCPR limit is to protect against boiling transition during flow excursions to maximum flow. The reduced flow LHGRFAC is based on the heat flux increase associated with an excursion to maximum flow. The flow dependent limits are bounding for single-loop conditions because of the limited core flow capacity in single-loop operations. The power dependent MCPR limit ($MCPR_p$) protects against exceeding the safety limit MCPR during anticipated operational occurrences from off-rated conditions. The power dependent LHGRFAC is used to protect against both fuel melting and 1% clad strain during anticipated system transients from off-rated conditions. The power dependent limits established for two-loop operation are appropriate limits for single-loop operation because the limiting events are unaffected by the single-loop mode of operation.

A.4 MAPLHGR LIMITS

SNP has established that the two-loop MAPLHGR limits for SNP 8x8 and 9x9-5 fuels multiplied by a reduction factor of 0.86 may be conservatively applied for single-loop operation. Application of this reduction factor ensures that the peak clad temperature from a single-loop operation LOCA is bounded by the two-loop LOCA analysis. The application of these limits is valid for average planar burnups of up to 50000 MWd/MTU and 55000 MWd/MTU for SNP 8x8 and 9x9-5 fuels, respectively (Reference 23).

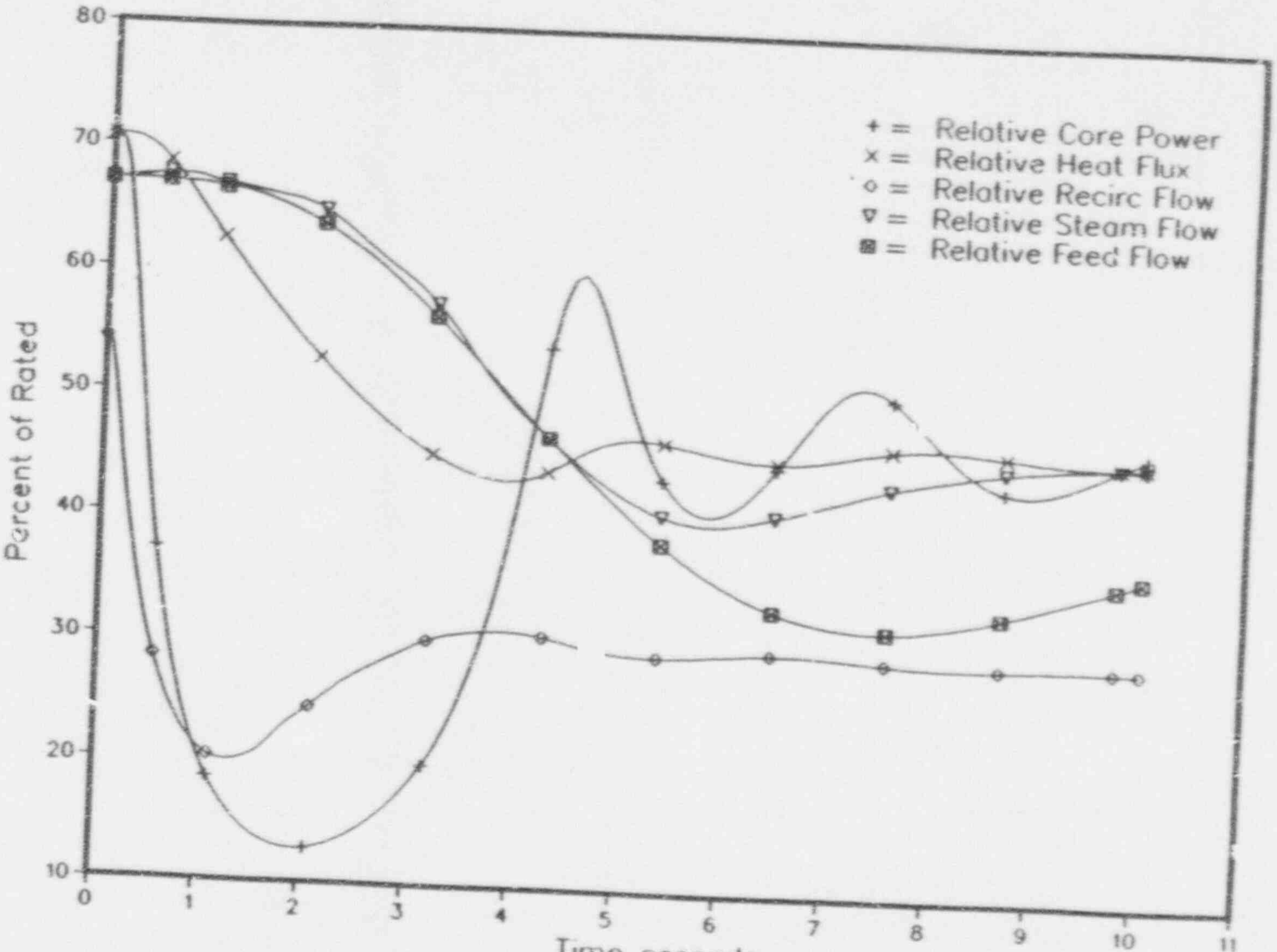

FIGURE A.1 PUMP SEIZURE EVENT SLO (POWER AND FLOWS)

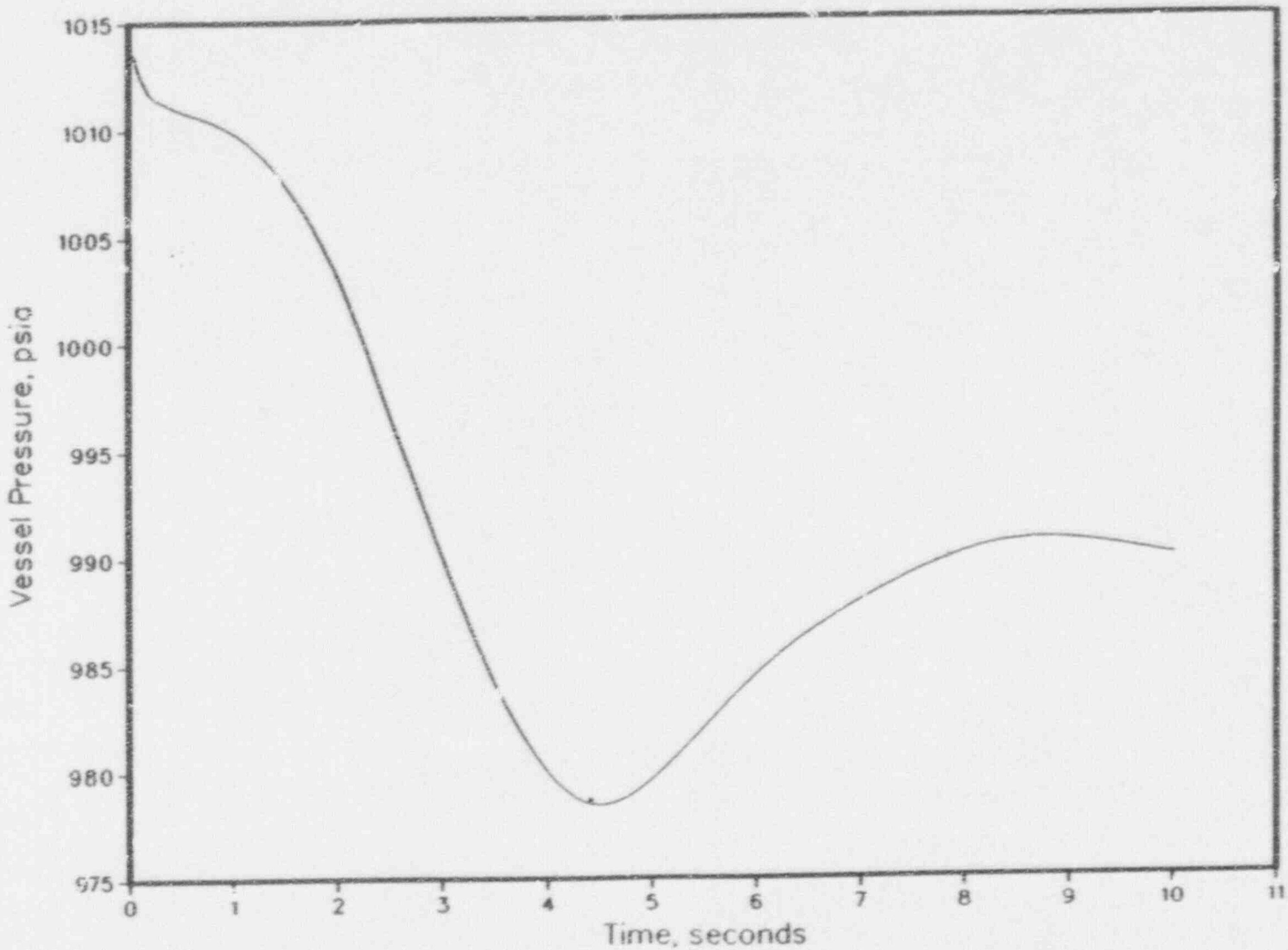

FIGURE A.2 PUMP SEIZURE EVENT SLO (VESSEL PRESSURE)

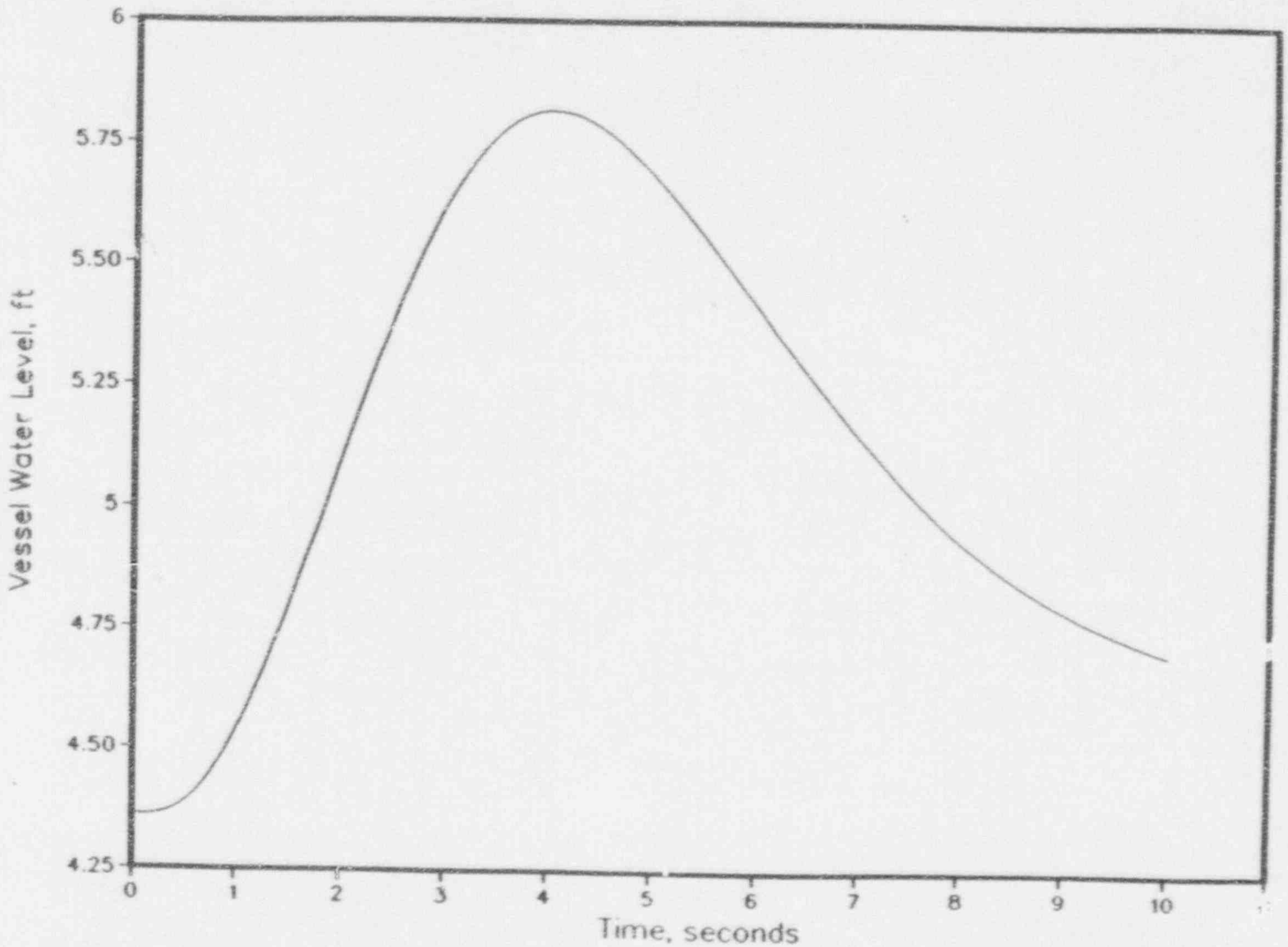

FIGURE A.3 PUMP SEIZURE EVENT SLO (WATER LEVEL ABOVE SEPARATOR SKIRT)

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GRAND GULF UNIT 1 CYCLE 6 PLANT TRANSIENT ANALYSIS

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