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# GRAND GULF NUCLEAR STATION UNIT 1

# REVISED FLOW DEPENDENT THERMAL LIMITS

Nuclear Engineering Services Department
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## 1.0 Introduction

This report documents the rationale for the revised $MCPR_f$ and $MAPFAC_f$ thermal limits for Grand Gulf Nuclear Station Unit 1 (GGNS-1). These revised limits incorporate:

a. The GGNS-1 specific analysis results calculated by the Advanced Nuclear Fuels (ANF) instead of the BWR generic analysis results generated by General Electric (GE),

b. The inherent design features of the Loop Manual mode of operation which preclude a two-loop flow runout event from being a credible event, and

c. The maximum achievable core flow rate without taking credit for the operator-controlled core flow limiter.

The revised $MCPR_f$ and $MAPFAC_f$ thermal limits were derived from GGNS-1 specific analyses performed by ANF for Cycles 2 and 3 (References 1 and 2). Additional conservatisms were imposed on the revised $MCPR_f$ limits as an allowance for future cycles. The probability of future changes in the $MAPFAC_f$ curve is low since it was statistically established based on varied operating conditions. Therefore, no additional margin of conservatism is necessary for the revised $MAPFAC_f$ limits.

## 2.0 Current $MCPR_f$ and $MAPFAC_f$

The $MCPR_f$ and $MAPFAC_f$ thermal limits protect the plant from exceeding the MCPR safety limit and the 120% overpower line, respectively, in the event the recirculation flow control valves inadvertently open (loop flow runout event). The limiting event for all modes of operation is the two-loop runout event. The current limits are dependent on the operator-controlled maximum core flow limiter which is set to either 102.5% or 107% of rated flow. The $MCPR_f$ limits are based on a BWR/6 generic analysis performed by GE for Cycle 1 and confirmed for Cycles 2 and 3 by ANF. The $MAPFAC_f$ limits for ANF fuel are based on GGNS-1 specific analysis performed by ANF for Cycle 2 and confirmed for Cycle 3.

## 3.0 Revised $MCPR_f$ and $MAPFAC_f$

The revised $MCPR_f$ and $MAPFAC_f$ limit curves are constructed to bound the GGNS-1 specific two-loop flow runout analyses results determined by ANF for Cycles 2 and 3. To eliminate the dependence on the operator-controlled maximum core flow limiter, the revised curves conservatively assume a maximum core flow of 110%, which bounds the maximum flow achievable for the limiting flow runout event (Reference 3). These curves, labeled "Non Loop Manual" for $MCPR_f$ and $MAPFAC_f$ are shown on Figures 1 and 2, respectively, and are applicable to all flow control modes of operation (the term Non Loop Manual is used to differentiate from the specific Loop Manual mode which is addressed separately below). The revised $MCPR_f$ curve incorporates the margin gain from the GGNS-1 specific analyses over the BWR generic GE analysis.

The Loop Manual mode is an operating mode which provides for independent manual control for each of the two recirculation flow control valves. Credit is taken for the fact that a two-loop flow runout event is not credible in the Loop Manual mode. In this mode, the flow control valves are controlled independently with no single failure or single operator action capable of inadvertently opening both valves simultaneously (Reference 4). Thus, in the Loop Manual mode, the limiting credible core flow increase event is the one-loop flow runout event. Table 1 provides the initial and final core flows for the one-loop flow runout event. The final core flows are conservatively calculated to bound the maximum achievable core flow rates for the one-loop flow runout event (see Section 4.0).

Separate $MCPR_f$ and $MAPFAC_f$ limits, applicable only when the plant is in the Loop Manual mode are constructed based on ANF analyses results for Cycles 2 and 3 using the conservative flow rate increases of Table 1 for a one-loop flow runout event. These limits, labeled "Loop Manual", are shown on Figures 1 and 2 for $MCPR_f$ and $MAPFAC_f$, respectively.

A numerical tabulation of the Non Loop Manual and the Loop Manual $MCPR_f$ and $MAPFAC_f$ revised limits is provided in Table 2. The current GGNS MCPR operating limit at rated power and flow (1.18) is retained with the revised $MCPR_f$ limits.

The revised $MCPR_f$ and $MAPFAC_f$ limits are compared in Figures 3 and 4 to the current GGNS-1 limits which were used during Cycles 2 and 3. The revised $MCPR_f$ limit for Non Loop Manual operations is approximately equal or more limiting than the current 102.5 % maximum core flow $MCPR_f$ limit. The revised $MAPFAC_f$ limit for Non Loop Manual operations is more limiting than both the current 102.5% and 107.% maximum core flow $MAPFAC_f$ limits. The revised $MCPR_f$ and $MAPFAC_f$ limits for Loop Manual operations, as expected, provide for operating flexibility as a result of the inherent design characteristics (i.e., independent control of the flow control valves) of the Loop Manual operating mode.

## 4.0 One-Loop Flow Runout Core Flows

During a one-loop flow runout event, a flow increase to maximum loop capacity occurs in one recirculation loop. The flow increase is caused by the inadvertent opening of the recirculation flow control valve (FCV) to the full open position. The position of the FCV in the other loop remains unchanged. In order to evaluate the effect on the CPR and LHGR during a one-loop flow runout event, it is necessary to establish the maximum core flow increase (i.e., final core flow rate minus initial core flow rate) for different initial core flow rates.

The total core flow rate is equal to the sum of the individual loop flow rates (the loop flow is defined as the loop jet pump flow). The loop flow rate is regulated by the recirculation FCV by adjusting the pressure drop across the loop. Under symmetric loop conditions (i.e., same flow rates in both loops) the FCV position can be directly correlated with the core flow rate. For the limiting two-loop flow runout event, the maximum open FCV position corresponds to a core flow rate that has been determined to be less than 110% of rated flow (Reference 3). The term "indicated loop flow" rate is defined as that loop flow rate which would result from a specific FCV position under symmetric loop conditions.

For asymmetric loop conditions, the FCV position does not uniquely determine the loop flow rate because the loop flow rate is also affected by the flow rate of the other loop. Under asymmetric loop conditions the actual loop flow rate may be different from the indicated loop flow rate, and therefore, the actual core flow rate may not equal the sum of the indicated loop flow rates. For the limiting one-loop flow runout event, the affected loop FCV is opened to the maximum open position. This position corresponds to the maximum indicated loop flow rate. The indicated loop flow rate of the other loop is unchanged since the FCV position remains the same.

Under asymmetric loop conditions following a one-loop runout event, the loop with the larger flow rate will have an actual flow rate higher than the indicated flow rate. This difference results because of the lower exit pressure exerted by the other loop in the lower plenum. The loop with the smaller flow rate will have an actual flow rate lower than indicated as a result of the higher exit pressure exerted by the other loop. Since the core flow rate is the sum of the actual loop flow rates, a relationship between the actual core flow rate (i.e., sum of the actual loop flow rates) to the indicated core flow rate (i.e., sum of the indicated loop flow rates) is required in order to analyze the one-loop flow runout event.

A conservative and simple relationship, applicable to all final core flow rates, is established by using the indicated core flow rate instead of the actual core flow rate. This relationship is used in evaluating the core flow increase following a one-loop runout event. This relationship is conservative (maximizes flow increase) since the indicated final core flow always bounds (i.e., is higher than or equal to) the actual core flow. The difference between the indicated and actual core flow rates is zero for the symmetric loop conditions and increases with an increasing degree of asymmetry. This relationship has been demonstrated by a GGNS plant startup test (one recirculation pump trip, Reference 5). This relationship is also supported by analysis using a computer model which has been validated against GGNS startup test data.

With the above relationship between the indicated loop and actual core flow rates, the change in the core flow rate during a one-loop runout event can be bounded for any set of initial conditions. The following steps are used to establish a conservative flow rate increase for the one-loop flow runout event:

a. Assume an initial mismatch of 10% of rated flow between the two loops based on the GGNS Technical Specifications, Section 3.4.1.3 (10% was assumed for all initial core flows even though the Technical Specifications limit the mismatch to 5% above 70% core flow).
b. Assume that the loop with the lower initial flow rate will be the affecied loop (maximizes flow increase).
c. Assume a maximum indicated loop flow rate of 110% of rated for the affected loop, following the runout event.
d. Establish the final core flow rate as the sum of the individual indicated loop flow rates.
e. Increase the final total core flow rate
calculations (a 2.5% conservative bias in flow rate).

The individual core channel flow rates are not affected by unequal loop flow rates. This is consistent with t assumption of complete lower plenum mixing which was employed by GE in their GGNS-1 single loop operation analysis and has been accepted by the NRC (Reference 6). As lower plenum mixing is governed by vessel design, the validity of this assumption will not be affected by the insertion of ANF fuel bundles.

The one-loop runout event final flow rates for various initial flow rates analyzed are presented in Table 1. These flow rates were calculated using the above five steps and represent a conservative upper bound to the actual flow rates expected following the one-loop runout event.

## 5.0 References


1. "Grand Gulf Unit 1 Cycle 2 Reload Analysis", XN-NF-86-35, Rev. 3, Exxon Nuclear company, Inc., Richland, WA, August 1986.

2. "Grand Gulf Unit Cycle 3 Reload Analysis", ANF-87-67, Rev. 1, Advanced Nuclear Fuels Corporation, Richland, WA, August 1987.

3. Smith. A. R. (GE) to J. G. Cesare (SERI), "GGNS Maximum Core Flow Capability", SEGE-87/125, 11/87.

4. NEDE-24011-P-A-4US, Appendix B.

5. Kingsley, O. D. (SERI) to Grace, J. N. (NRC), "Final Summary Startup Test Report 12', AECM-8610066, 2/86.

6. Kingsley, O. D. (SERI) to Denton, H. R. (NRC), PCOL-86/05, AECM-86/0092, 3/86 ("GGNS Single Loop Operation Analysis", GE, 2/86 attached).

Table 1

Core Flows for the One-Loop Flow Runout Event

| Initial Core Flow (%) | Final Core Flow (%) | Flow Increase (% of Rated) |
|---|---|---|
| 100 | 110 | 10 |
| 90 | 105 | 15 |
| 80 | 100 | 20 |
| 70 | 95 | 25 |
| 60 | 90 | 30 |
| 50 | 85 | 35 |
| 40 | 80 | 40 |
| 30 | 75 | 45 |

Table 2

Revised Flow Dependent Thermal Limits

| Core Flow (%) | Non Loop Manual $MCPR_f$ | Loop Manual $MCPR_f$ | Non Loop Manual $MAPFAC_f$ | Loop Manual $MAPFAC_f$ |
|---|---|---|---|---|
| 105 | 1.18 | 1.18 | 1.0 | 1.0 |
| 91.0 | - | - | 1.0 | - |
| 90 | - | - | 0.992 | - |
| 86.3 | 1.18 | - | - | - |
| 84.3 | - | - | - | 1.0 |
| 80 | 1.212 | - | 0.904 | 0.977 |
| 73.4 | - | 1.18 | - | - |
| 70 | 1.271 | 1.193 | 0.827 | 0.928 |
| 60 | 1.345 | 1.243 | 0.757 | 0.880 |
| 50 | 1.441 | 1.314 | 0.695 | 0.837 |
| 40 | 1.566 | 1.414 | 0.638 | 0.794 |
| 30 | 1.727 | 1.545 | 0.586 | 0.752 |

FIGURE 1

REVISED FLOW DEPENDENT MCPR LIMIT

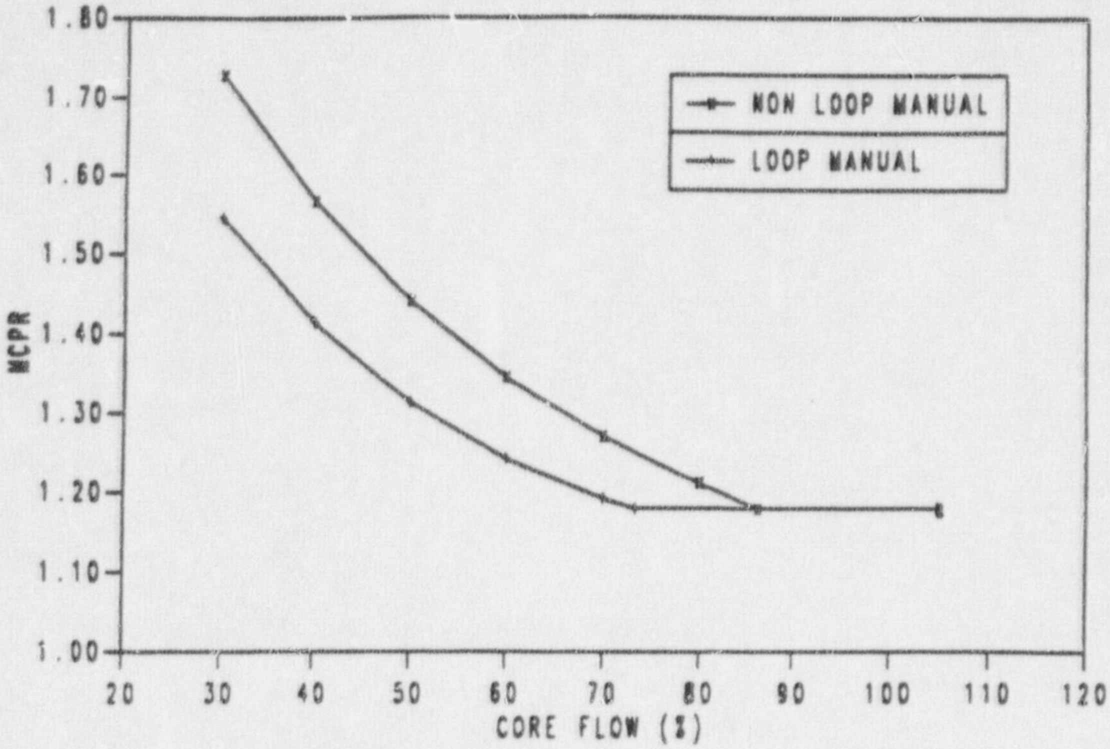


FIGURE 2

REVISED FLOW DEPENDENT MAPFAC LIMIT

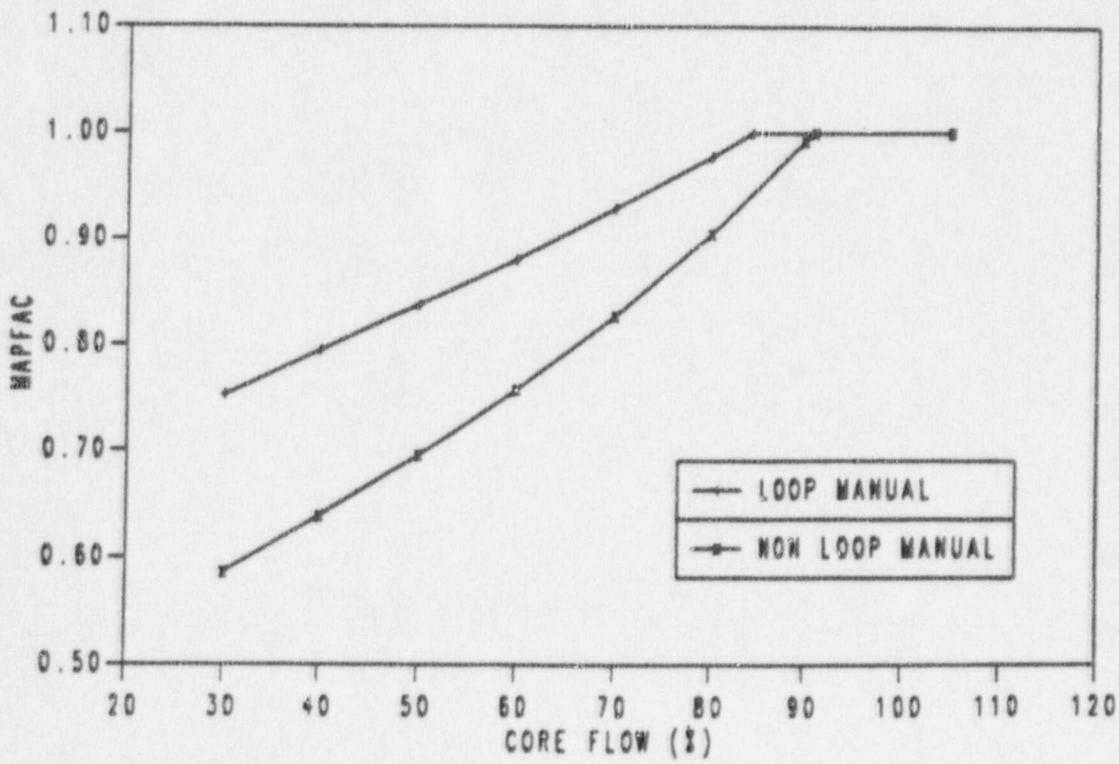

FIGURE 3

FLOW DEPENDENT MCPR LIMITS COMPARISON

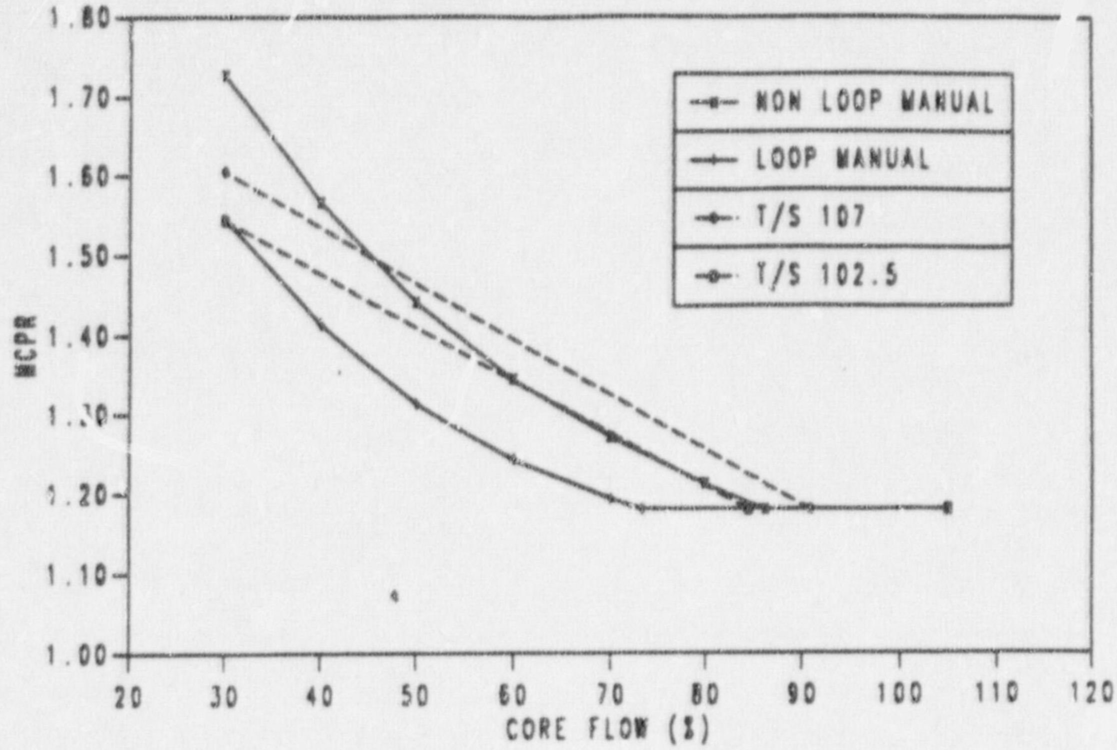


FIGURE 4

FLOW DEPENDENT MAPFAC LIMITS COMPARISON