SINGLE LOOP OPERATION SUMMARY REPORT

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NOTICE

This report is derived in part through information provided to Washington Public Power Supply System (Supply System) by Advanced Nuclear Fuels Corporation. It is being submitted by the Supply System to the U.S. Nuclear Regulatory Commission in partial support of the WNP-2 Application For Technical Specification Changes Relating to Operation With One Recirculation Loop. The information contained herein is true and correct to the best of the Supply System's knowledge, information, and belief.

WNP-2

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1.0 INTRODUCTION

The Supply System is currently permitted to operate WNP-2 with one recirculation loop out of service at power levels up to 72 percent power and for burnups up to 15,000 MWD/MTU on the reload fuel. The initial core fuel is permitted to operate to burnups of 44,000 MWD/MTU with one recirculation loop out of service. This report summarizes the analysis performed by Advanced Nuclear Fuels Corporation (ANF) in support of operation of WNP-2 in single loop (SLO) at power levels up to 75 percent power and for burnups up to 35,000 MWD/MTU on the reload fuel.

The analysis summarized here and developed more thoroughly in the referenced documentation considered transient analysis effects, the reactor safety limit, reactor stability, the effects of the design basis loss of coolant accident (LOCA), and a confirmatory analysis of the design basis pump seizure event. The results of the analysis of the above items are discussed in turn in this report.

The results of these analyses have identified several Technical Specification changes. These proposed Technical Specification changes are identified by title in Table 1.1. The detailed proposed Technical Specification changes are attached to this report.

TABLE 1.1

Proposed Technical Specification Changes

	Index
2.2.1	Reactor Protection System Instrumentation Setpoints
3/4.2.1	Average Planar Linear Heat Generation Rate
3/4.2.2	APRM Setpoints
3/4.2.3	Minimum Critical Power Ratio
3/4.2.6	Power/Flow Instability
3/4.2.7	Neutron Flux Noise Monitoring
3/4.3.6	Control Rod Block Instrumentation
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3/4.4.1	Recirculation System
B 3/4.2.1	Average Planar Linear Heat Generation Rate
B 3/4.2.6	Power/Flow Instability
B 3/4.2.7	Neutron Flux Noise Monitoring
B 3/4.3.10	Neutron Flux Monitoring Instrumentation
B 3/4.4.4.1	Recirculation System

The results of the analyses reported here are considered to be applicable to WNP-2 Cycle 3 and subsequent fuel cycles containing ANF and General Electric 8x8 fuel of similar design. In general, the results of the analyses demonstrate that SLO operation is bounded by a single operational limit which, in some cases, is lower than the two loop operational limit or by the two loop operational limit in the case of MAPLHGR. Specifically, the analysis demonstrates that SLO operation is provided with sufficient protection by an MCPR value of 1.35 and by use of the two loop MAPLHGR values for SLO operation.

2.0 TRANSIENT ANALYSIS

ANF has analyzed operation of the WNP-2 reactor for the SLO condition (Reference 8.1). Transient analyses postulated to occur during SLO operation have been performed. One goal of the analyses performed was to satisfactorily demonstrate that the SLO condition can be satisfactorily bounded by a single MCPR value.

The transient analyses performed and reported here include:

- Load Rejection Without Bypass (LRWB)
- Feedwater Controller Failure (FWCF)
- Recirculation Pump Trip
- Recirculation Flow Runup
- Control Rod Withdrawal Error (CRWE)

The conclusions of these analyses are applicable to future WNP-2 fuel cycles containing ANF and GE fuel of the current 8x8 design.

2.1 Analysis Basis

The WNP-2 SLO transient analysis was performed using ANF methodology (Reference 8.2). This methodology is consistent with that used in the normal WNP-2 reload analysis. Normally, the transient analyses are performed at 104.2 percent of rated core thermal power which corresponds to the 105 percent steam flow condition. To support operation at 75 percent power in the SLO condition, these analyses were performed at 104.2 percent of the 75 percent power state or 2596.9 Mwt. For analysis purposes, the core flow was assumed to be 54.0 Mlbm/hr. The steam flow at this power level is 10.62 Mlbm/hr. In addition, normal scram speed, Technical Specification scram delay, and a integral power multiplier of 110 percent were assumed for all transient analyses reported here.

The system conditions at which the SLO transients were evaluated are summarized in Table 3.1 of Reference 8.1. The steam flow/enthalpy characteristic from Reference 8.3 was used to initialize the plant

transient simulation code COTRANSA (Reference 8.4). A jet pump M-ratio of 3.2 was used for initialization of the COTRANSA model at 54.0 Mlbm/hr core flow. The analyses were performed for a core configuration representative of Cycle 3.

2.2 Results of the Analysis

The limiting transient events for WNP-2 have been analyzed for the maximum expected power state during SLO. The results of these analyses are summarized in Table 2.1. The values given for CRWE are conservative, bounding values for the CRWE event at the analyzed SLO power/flow conditions. The reported operating limit CPR values reflect calculated delta CPR values of 0.22 for ANF fuel and 0.26 for GE fuel. These values are conservatively large because they are calculated from an initial MCPR that is much larger than the safety limit MCPR. Experience has shown that transient analyses performed at higher initial MCPR values result in higher calculated delta CPR values. Thus, the reported operating limit MCPR values represent conservative bounding values for the CRWE event at the limiting SLO conditions.

The LOCA-ECCS analysis discussed in Section 5.0 was initialized at an MCPR value of 1.35. As shown in Table 2.1, this value bounds the MCPR operating limit requirements for all SLO anticipated operational occurrences. Therefore, a value of 1.35 has been established as the required MCPR operating limit for single loop operation.

The established value of 1.35 bounds the requirements for SLO operation. Therefore, the single loop transient analyses need not be performed on a cycle-by-cycle basis. The only exception to this is, in the event the two loop CRWE event operating limit exceeds the current value of 1.26, the single loop CRWE results will be reviewed to ensure they remain conservative.

In the single loop configuration, the additional constraint of the reduced flow MCPR operating limits is no longer required. A flow run up which would encroach upon the MCPR safety limit is not possible as the pump in the idle loop is not running. An inadvertent start of the idle pump cannot effect flow appreciably as the pump is interlocked to preclude starting unless its associated flow control valve is at the minimum position.

Operation in single loop is precluded above the 80 percent rod line when total core flow is less than 39 percent of rated core flow. This limits the most severe single pump run up to a flow increase from 39 percent to approximately 55 percent total core flow. This flow increase is not of sufficient magnitude to violate the MCPR safety limit if the transient initiates on the established single loop MCPR operating limit of 1.35. This can be seen from the WNP-2 Cycle 3 Plant Transient Analysis (XN-NF-87-24), Figure 5.1 (Reference 8.5).

Completion of the SLO CRWE analysis reported in Table 2.1 and demonstration that the results of this analysis are bounded by the proposed single MCPR operating limit for SLO operation justifies deletion of the 3.3 percent penalty previously imposed on instrument set points while in SLO operation. This penalty was originally imposed to compensate for differences in drive flow vs. core flow between single and two loop operation. Completion of a CRWE analysis at the limiting conditions for single loop operation eliminates the need for this penalty.

TABLE 2.1

A SUMMARY OF SLO TRANSIENT ANALYSIS RESULTS

Event	Required SLO MCPR Limit	
	ANF Fuel	GE Fuel
LRWB	1.21	1.24
FWCF	1.09	1.09
Pump Trip	1.07	1.09
CRWE	1.29*	1.33*

*These are conservative, bounding values.

3.0 SAFETY LIMIT

The MCPR fuel cladding integrity safety limit was analyzed using the methodology of Reference 8.6 to evaluate plant measurement and power prediction uncertainties. In SLO operation, measurement and prediction uncertainties of core flow, radial power distribution, and axial power distribution increase. The uncertainties used in the safety limit evaluation are given in Table 5.1 of Reference 8.1. The XN-3 correlation (Reference 8.7) is used to predict initial heat flux based on the evaluated uncertainties.

During SLO operation at a MCPR of 1.07, at least 99.9 percent of the fuel rods avoid boiling transition (95 percent confidence level). Therefore, the evaluation supports a safety limit of 1.07 for SLO operation for all fuel types. This is an increase of 0.01 over that for two loop operation.

4.0 STABILITY ANALYSIS

A stability analysis has been performed for SLO conditions for Cycle 3. The computations were performed by the same methods and techniques as those used for the two loop Cycle 3 stability analysis. The most limiting Cycle 3 SLO decay radios were determined to be identical to the Cycle 3 two loop operation values.

5.0 LOCA ANALYSIS

The results of a LOCA-ECCS analysis for WNP-2 to support SLO are reported in Reference 8.8 and summarized here. These computations were performed for the generically approved ANF EXEM/BWR model (References 8.9 and 8.10) in accordance with Appendix K of 10CFR50, and the results comply with the 10CFR50.46 Criteria. This is the same methodology utilized in the WNP-2 two loop analysis. The SLO condition selected for this analysis was 75 percent power and 50 percent flow.

5.1 Jet Pump BWR ECCS Evaluation Model

The ANF EXEM/BWR ECCS Evaluation model codes were used for this SLO LOCA-ECCS calculation. The codes which comprise EXEM consist of RODEX (Reference 8.11), RELAX (Reference 8.12), FLEX (Reference 8.13), and HUXY/BULGEX (References 8.14 and 8.15). The latest versions of these codes were used for this SLO analysis, and they are referenced in the generic WNP-2 two loop analyses (References 8.16 and 8.17).

The system behavior during a LOCA is determined primarily by the LOCA break parameters: break location, break size, and break configuration together with the ECCS systems and plant geometry. Variation in core parameters produce only secondary effects on the system behavior. By using bounding core neutronic parameters, the LOCA-ECCS results established by this analysis apply for future cycles unless substantial changes are made in the plant operating conditions, plant hardware or core design such that the analysis no longer bounds the plant conditions.

The calculation was performed for a core composed of all ANF 8x8 fuel. Other than changes mentioned in Reference 8.8, the system blowdown model remains the same as for the two loop model (Reference 8.17).

The system blowdown calculations are followed by HOT CHANNEL calculations. The core geometry is identical with that used in the two loop analysis. The initial conditions were adjusted to correspond to those for the single loop operating point. The power, axial peaking, and flow of the hot assembly were determined by an XCOBRA thermal hydraulics calculation to support a MCPR consistent with the initial conditions. The nodalization and geometry used in the reflood calculation are identical to those of the two loop analysis. In the FLEX code, the intact loop in not modeled in detail because intact loop flows are insignificant at the time of rated low pressure core spray. Thus, no changes were required in the FLEX nodalization or geometry. The initial conditions for the reflood calculation are entirely determined by the system blowdown calculation.

The HUXY/BULGEX heatup calculation of the hot plane was done identically with previous two loop analyses. Fuel stored energy, thermal gap conductivity and dimensions were obtained from RODEX2 as a function of power and exposure. Time of rated spray, decay power, heat transfer coefficients, and coolant conditions were obtained from RELAX, and time of hot-node-reflood came from FLEX. Bounding fission and actinide product decay heat obtained with end-of-cycle neutronics in the system blowdown calculation assure that the power input to the HUXY/BULGEX heatup calculation is conservative. Appendix K spray heat transfer coefficient are used for the spray cooling period. For heated fuel rods, the values of 1.5, 3.0, and 3.5 BTU/hr-ft2-F are used in the interior, corner, and peripheral rods respectively. For the unheated fuel channel and water rod surfaces, the values of 5.0 and 1.5 BTU/hr-ft2-F are used. For the reflood period, the Appendix K reflood heat transfer coefficient value of 25 BTU/hr-ft2-F is used. Peak cladding temperature (PCT) and the cladding oxidation percentage are specifically determined for the ANF 8x8 fuel geometry.

5.2 Results of the Analysis

Computations were performed using the referenced model to confirm the most limiting break in a recirculation pipe for WNP-2 under SLO conditions. Based on the identified break, MAPLHGR results were then obtained at the most limiting fuel exposure. The results are discussed in detail below.

5.2.1 Break Spectrum

The existing break spectrum for WNP-2, applicable to two loop operation, showed the most limiting break to be a split break in the recirculation suction piping with an area of 6/10 of the double ended pipe area (0.6 DES/RS) (Reference 8.16). A larger break occurring during SLO might cause an earlier Critical Heat Flux (CHF) to occur near the core midplane resulting in higher Peak Clad Temperatures (PCTs) than those calculated for the 0.6 DES/RS break. Therefore, analysis of a LOCA during SLO was made for two suction break sizes at beginning of life (BOL) fuel exposure to determine if phenomena unique to SLO initial conditions would cause a change in the previously calculated limiting break. The two breaks analyzed were a double ended guillotine break on the recirculation pump suction side (1.0 DEG/RS) and the limiting 0.6 DES/RS. A third analysis for a double ended guillotine break on the recirculation pump discharge side (1.0 DEG/RD) was performed through the time of rated Low Pressure Core Spray (LPCS) to confirm the limiting break remained in the suction line.

The calculated PCTs for LOCAs initiated from both normal operation and SLO for the 0.6 DES/RS and the 1.0 DEG/RS breaks are shown in Reference 8.8. The calculated PCT for the 0.6 DES/RS break is higher than the 1.0 DEG/RS break for both SLO and normal two loop operation by approximately the same amount. These results indicate clearly that the break spectrum results presented in Reference 8.16 also apply for SLO. In addition, the peak fuel rod stored energy and surface temperatures at the time of rated LPCS were compared for the 0.6 DES/RS and the 1.0 DEG/RD breaks. This comparison showed these temperatures for the 0.6 DES/RS break would be higher than those for the pump discharge side break.

5.2.2 MAPLHGR Results

The MAPLHGR results were obtained by analysis of the 0.6 DES/RS break at the most limiting fuel exposure (Reference 8.17). These results show that the MAPLHGR versus exposure curve for ANF fuel applies for both two loop operation and SLO.

The PCT values for the two full SLO breaks are approximately 100°F higher than the corresponding breaks in the two loop analysis because the recirculation flow contol valve is not in the full open position. This added resistance does not affect the system blowdown calculation time because the flow at the break is choked during the system blowdown. During the latter part of the blowdown, the break is unchoked and

the additional resistance from the recirculation flow control valve increases the reflood calculation time by approximately ten seconds. Thus, the SLO PCT values are higher than the two loop PCT values due to this system effect and the SLO core flow effects but there is still more than 400°F of margin to the PCT limit of 2,200°F.

The results presented here for the limiting break (0.6 DES/RS) and highest fuel exposure with maximum stored energy show that the calculated PCT is 1,884°F for a MAPLGHR of 13 kw/ft (Reference 8.8). Since the PCT and metal-water reaction percent are well within the Appendix K of 10CFR50 limits, it is concluded that the MAPLHGRs for ANF 8x8 fuel as calculated for two loop operation apply for SLO. A MAPLHGR reduction factor for ANF fuel in WNP-2 is not required for SLO.

6.0 PUMP SEIZURE ANALYSIS

The seizure of a recirculation pump is considered as a design basis accident event (Reference 18.8). It is a very mild accident relative to other design basis accidents such as the LOCA. The pump seizure event is a postulated accident in which the recirculation pump impeller speed is rapidly reduced to zero. This causes a rapid decrease in core flow and a decrease in the heat removal rate from the fuel rods. Although the vessel water level increases, a high level trip does not occur in the analysis. However, even without a scram, the power decreases consistent with the core flow decrease until natural circulation conditions occur.

A pump seizure accident was analyzed for WNP-2 to confirm the insignificance of this event relative to the design basis LOCA (Reference 8.1). The core remains covered and natural circulation conditions are approached within three seconds. Any fuel rods which experience boiling transition would be expected to be in the film boiling mode for a short period. In addition, the film boiling would be limited to small, localized areas in the affected fuel assemblies. Because of this short duration, fuel failures due to overheating or clad strain would not be expected as a result of this accident. The consequences of this event are bounded by the LOCA where fuel failures are assumed to be extensive.

7.0 SUMMARY

The results of the analyses performed by ANF for WNP-2 in SLO support the use of a single bounding MCPR operating limit of 1.35 and two loop ANF fuel MAPLHGR limits for SLO for future fuel cycles.

Operation in the single loop mode results in higher uncertainties for core flow, radial power, and axial power. Considering these SLO uncertainties, the MCPR safety limit was determined to increase by 0.01 to 1.07. However, the two loop MCPR limits at SLO flow conditions bound the required MCPR limits for SLO conditions including the higher safety limit MCPR.

With regard to reactor stability, the most limiting Cycle 3 SLO decay ratios were determined to be identified to the Cycle 3 two loop operation values.

A postulated pump seizure accident was evaluated for SLO conditions. The event is less severe than the design basis loss of coolant accident (LOCA). The radiological consequences of this accident are well within the 10CFR100 limits.

Single loop operation of WNP-2 with the two loop ANF fuel MAPLHGRs assures that the emergency core cooling systems for the WNP-2 plant will meet the U.S. NRC acceptance criteria of 10CFR50.46 for loss-of-coolant accident breaks up to and including the double-ended severance of a reactor coolant pipe. That is:

1. The calculated peak fuel element clad temperature does not exceed the 2,200°F limit.

2. The calculated total oxidation of the cladding nowhere exceeds 17 percent times the total cladding thickness before oxidation.

3. The calculated maximum hydrogen generation does not exceed 1 percent of the zircaloy associated with the active fuel cladding in the reactor.

4. The LOCA cladding temperature transient is calculated to be terminated at a time when the core is still amenable to cooling.

5. The system long-term cooling capabilities provided for the initial core and subsequent reloads remain applicable to ANF fuel.

8.0 REFERENCES

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8.16 "LOCA Break Spectrum Analysis For a BWR 5", XN-NF-85-138(P), Exxon Nuclear Company, Inc., December 1985

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NOTES

1. Need letter from ANF agreeing to 1.35 MCPR.

2. Setpoint changes justified by CRWE calculation which G.E. had not done. Need to add CRWE discussion which should be buttressed by letter.