14.4 EXCESS LOAD EVENT

14.4.1 IDENTIFICATION OF EVENT AND CAUSE

The primary function of the turbine control valves (governor valves on Unit 2) is to regulate the steam to the high pressure turbine. These four valves are located just downstream of the main stop valves (throttle valves on Unit 2). When operating at HFP (2737 MWt), these valves can only demand an additional 10% steam flow when full open. To regulate the secondary pressure and to reduce the number of times the MSSVs are actuated, there are two dump valves to the atmosphere and four turbine bypass valves to the condenser with a capacity of 5% and 40% of rated thermal power (RTP), respectively. The atmospheric dump valves are located outside-containment and upstream of the MSSVs. The turbine bypass valves are upstream of the main stop valves and downstream of the MSIVs.

An Excess Load event is defined as any rapid, uncontrolled increase in SG steam flow other than an SLB (Section 14.14). The full opening of the turbine control valves, atmospheric dump valves, or turbine bypass valves during steady-state operation would result in the most limiting Excess Load event.

The most limiting Excess Load event at HFP is an inadvertent opening of the atmospheric dump and turbine bypass valves. The full opening of the atmospheric dump and turbine bypass valves is more limiting than the full opening of the turbine control valve at HFP because the combination of the atmospheric dump and turbine bypass valves has more heat removal capacity than the turbine control valves (i.e., 45% compared to less than 10%, respectively, at HFP).

For the zero power Excess Load event, the most limiting case is a complete opening of the turbine control valves. The turbine control valves have more heat removal capacity than the atmospheric dump and turbine bypass valves at HZP. Thus, the full opening of the turbine control valves causes a larger power rise due to a more severe steam flow mismatch than the full opening of the atmospheric dump and turbine bypass valves. Consequently, the full opening of the turbine control valves will result in the highest power and highest peak LHR.

14.4.2 SEQUENCE OF EVENTS

An Excess Load event can approach the DNBR and LHGR SAFDLs and the RCS Pressure Upset limit. For the most limiting events, the initial margins maintained by the LCOs in conjunction with the action of the VHPT will prevent exceeding these limits. Additional protection is provided by the TM/LP, Rate of Change of Power or Low SG Pressure Trip. Since no fuel pin failures are postulated to occur, the site boundary dose criteria contained in the 10 CFR 50.67 guidelines will not be approached.

14.4.2.1 Zero Power Case

The limiting Excess Load event at zero power is postulated to be initiated by the full opening of the turbine control valves. The result of the increase in steam flow is a power mismatch between the primary and secondary systems.

The immediate response to the additional steam flow demand is a rapid decrease in SG pressure. As the pressure rapidly decreases, the level in the SG initially increases due to void formation. The SG temperature will also rapidly decrease as more heat (steam) is being extracted than is being added. Since the reactor is not producing any heat, the secondary side cools down the primary side. The RCS temperatures will decrease and the pressurizer pressure and level will consequently decrease. With the decreasing level and pressure, the charging pumps and pressurizer heaters will automatically turn on. Since the pressurizer pressure and level control systems are not safety grade, no credit is allowed for this automatic feature to mitigate the decrease in level and pressure.

In the presence of a negative MTC (depending on the boron concentration, the MTC can be either positive or negative) and a negative FTC (always negative), positive reactivity feedbacks will occur in response to the decreasing coolant and fuel temperatures. These feedbacks cause an increase in core power, and then an increase in core heat flux and slow down the decrease in core temperatures. Without any negative feedbacks to reduce the positive reactivity insertion, the core power will increase at an exponential rate until a VHPT signal initiates a reactor trip.

The HZP Excess Load event can be postulated to be initiated at various conditions, including:

- maximum cooldown rate maximum excess load and maximum MFW, or
- lower cooldown rate with less than maximum excess load, less or no MFW, or a reactivity feedback representative of anytime during the cycle.

The HZP events that present a slower approach to the VHPT may not reach the sensed VHPT setpoint under some conditions. The events that do not reach the sensed VHPT setpoint have other trips available to protect the SAFDLs. These RPS trips include the Low SG Pressure Trip, Low SG Level Trip, or the Rate of Change of Power Trip. The postulated transients initiated at HZP with a less than maximum cooldown or reactivity insertion rate would incur at least one of these trips, which would preclude or mitigate any significant increase in power that would challenge the SAFDLs.

A conservative HZP Excess Load event is analyzed as the licensing basis event regarding the SAFDLs. This event conservatively assumes a maximum excess load of 120% and maximum MFW flow to maximize the RCS cooldown rate and peak power. In addition, a most negative Technical Specifications MTC limit and least negative FTC are used to maximize the positive reactivity insertion during the RCS cooldown. Only the VHPT, including uncertainties, is credited for this event. This trip is delayed by conservatively modeling decalibration of the sensed excore detector power during the cooldown. Also, a very conservative Fq is used at the hot spot along with a thermal conductivity and melt temperature for 8 wt% gadolinia fuel rods to maximize the challenge to the FCM SAFDL. This analysis produces a very conservative simulation of the HZP Excess Load event.

The Excess Load event presented herein at HZP was initiated at the conditions given in Table 14.4-1.

The sequence of events for the HZP case is presented in Table 14.4-2. Figures 14.4-7 to 14.4-12 show the NSSS transient response for core power, core heat flux, RCS temperature, RCS pressure, SG pressures and reactivities.

HZP cases were run to evaluate return-to-power following reactor scram. The reactor returned to power following scram when a MSIV is assumed to fail to close for a minimum shutdown margin of 3500 pcm. Boration from HPSI returns the core to a subcritical condition.

If MFW is assumed to not respond to the increased steam load, then the sensed VHPT setpoint may not be reached. The scenario with minimum MFW reaches the Low SG Pressure Trip setpoint. It is conservatively assumed that the AFAS occurs at event initiation, resulting in an early delivery of AFW flow to both SGs. Closure of the MSIV on one SG causes SG pressure to diverge, which results in AFW Block, diverting AFW flow to the "intact" SG. The water level in the intact SG increases. The analysis of this scenario shows that the operator has greater than ten minutes after event initiation to control AFW and stabilize the plant and to prevent further progression of the event. This minimum MFW case also produces the most limiting post scram return to power of those initiated from the HZP condition.

The HZP Excess Load event also provides input to the mechanical design analysis of cladding strain described in UFSAR Chapter 3.

14.4.2.2 Full Power Case

The HFP Excess Load event is analyzed via an MTC spectrum for purposes of identifying the DNBR and FCM limiting cases. The initial margin maintained by the LCOs in conjunction with the action of the VHPT prevents the DNBR from going below the SAFDL and protects against FCM.

The full power case is initiated at 100% of rated power and at the LCOs. The event is postulated to be initiated by the full opening of the atmospheric dump and bypass valves. The result of the increase in steam flow is a power mismatch between primary system output and secondary system demand.

The immediate NSSS response to the increase in steam flow demand is a rapid decrease in SG pressure and temperature. The rapid decrease in pressure will cause the SG level to initially increase due to void formation. The decrease in SG temperature will cause the RCS temperatures to decrease. The decreasing RCS temperatures will cause the RCS pressure and coolant volume to rapidly decrease. As the pressurizer pressure and level continue to decrease, the charging pumps and pressurizer heaters will automatically turn on and RCS letdown will stop. Since the pressurizer control system is not safety grade, the analysis does not take credit for these automatic features to mitigate the consequences of the event.

The analysis assumes a negative MTC and a negative FTC that will result in a positive reactivity feedback. The additional positive reactivity will cause an increase in core power and then an increase in core heat flux. The increasing core heat flux will slow down the decrease in RCS temperatures.

With a high fuel rod gap conductance, H_{gap}, the core heat flux will closely follow the core power and reach a maximum slightly below the peak core power.

The Excess Load event initiated from RTP is one of the events analyzed to establish input to the statistical setpoint calculation.

Main Feedwater is modeled to follow steam demand until SG isolation occurs. The thermal margin cases (DNBR and FCM) are completed prior to SG isolation. For the return to power (long term) cases, SG pressures drop to the SG isolation setpoint. The limiting cases assume failure of an MSIV to close. The SG connected to the stuck open MSIV depletes to AFAS setpoint, AFW Block due to SG differential pressure occurs. AFW Block results in no AFW flow to the "ruptured" SG and full flow to the unaffected SG. Operator action after 10 minutes is required to control AFW and stabilize the plant.

The reactor remained subcritical following a scram for all HFP cases except for those assuming failure of an MSIV to close. The DNB and FCM analyses at the time of peak post-scram power did not result in fuel failure. At 600 seconds (10 minutes), the analysis assumes the operator shuts off steam flow to the atmospheric dump valves, which isolates steam flow from the SG with the closed MSIV. The SG with the stuck open MSIV would continue to blowdown until dry, or until operator action successfully isolates that SG.

14.4.3 CORE AND SYSTEM PERFORMANCE

14.4.3.1 Mathematical Models

The transient response of the RCS and steam systems to the Excess Load event was simulated using the S-RELAP5 thermal-hydraulic code consistent with the methodology in Reference 1. The XCOBRA-IIIC fuel assembly thermal-hydraulic code was used to calculate the flow and enthalpy distributions for the entire core and the DNB performance for the DNB-limiting assembly. The limiting assembly DNBR calculations were performed using an approved DNB correlation. For the thermal margin calculations, the overall core conditions calculated by S-RELAP5 during the transient were used as the input to the XCOBRA-IIIC calculation. The limiting design axial power profile (a top peaked axial power distribution) was used for this simulation for conservatism. These computer codes are described in Section 14.1.4.1.

The Excess Load Event can exhibit a prolonged cooldown after scram has occurred. The prolonged cooldown results in safety systems being activated, which introduces the potential for single failures. The worst single failure is a failure of a MSIV to shut. This failure results in conditions that are generally the same as those encountered during a Steam Line Break; therefore, the Steam Line Break methodology is used to analyze the Excess Load with failure of an MSIV to shut. The methodology is described in Section 5.4 of Reference 1. The Steam Line Break methodology requires an assumption that the worst CEA does not insert. The potential exists to overcome the negative reactivity inserted by the CEAs, resulting in very high power peaking factors in the vicinity of the stuck CEA. The Steam Line Break methodology includes iteration between a neutronics and thermal hydraulics code to converge on the thermal hydraulic and power conditions in the vicinity of the stuck CEA in order to determine post-scram DNB and FCM.

14.4.3.2 Input Parameters and Initial Conditions

The key input parameters and initial conditions assumed in the analysis of the fuel SAFDLs at or near the time of trip, are given in Table 14-4.1.

For the HZP case, it was assumed that the plant is in Mode 2 conditions. A Moderator Density Table, biased to support the HFP most negative MTC limit was used. The excore power signal was credited as input to the VHPT. This results in the closest approach to the DNBR and LHGR SAFDLs. For the HFP case, a spectrum of negative MTCs and a least negative Doppler fuel temperature feedback were analyzed. Turbine operation in automatic and manual modes was assumed.

An FTC corresponding to EOC conditions with an uncertainty causing a least negative FTC was used in the analysis since this FTC causes the least amount of negative reactivity change for mitigating the transient increase in core heat flux.

For short term HZP thermal margin analyses, all three charging pumps are assumed to be operating and injecting a maximum flow of 50 gpm. All letdown control valves are assumed closed. This configuration maximizes the primary side cooldown and increases the positive reactivity insertion.

The Pressurizer Pressure Control System (PPCS) was assumed to be inoperable because this minimizes the RCS pressure during the event and, therefore, reduces the calculated DNBR. All other control systems were assumed to be in manual mode of operation and have no impact on the results of this event.

An analysis was performed to evaluate the return-to-power. The excess load event initiated from HFP conditions resulted in an excessive cooldown of the RCS. An FTC and MTC corresponding to EOC conditions were used since EOC values add the most positive reactivity during the cooldown. The HFP case assuming failure of a MSIV to close with delayed operator response to control AFW, shut the atmospheric dump valves and isolate the SG by shutting the MSIV or turbine control valves (10 minute response, which is past the time of return-to-power) resulted in the limiting scenario. The return-to-power scenario assumed no charging flow and assumed feedwater isolation valve leakage. This scenario resulted in a turnaround in the power decrease (a return-to-power) that is shortly thereafter arrested by boron being injected via HPSI.

The Excess Load event is categorized as an AOO for which the RPS trips and/or sufficient initial steady-state thermal margin, maintained by the LCOs, prevent acceptable limits from being exceeded. The analysis that evaluates the approach to the fuel SAFDLs at or near the time of reactor trip is protected by RPS trips and initial thermal margin. The subcritical margin calculation is protected by RPS trips, initial thermal margin, and ESFAS.

14.4.3.3 Results

Table 14.4-2 contains the sequence of events for the zero power case to determine the approach to the DNBR and LHGR SAFDL. Figures 14.4-7 through 14.4-12 present the transient behavior of the core power, core average heat flux, RCS temperatures, RCS pressure, SG pressure, and various reactivities versus time.

Table 14.4-3 contains the sequence of events for the full power case to determine the approach to the DNBR and LHGR SAFDLs. Figures 14.4-1 through 14.4-6 present the transient behavior of the core power, core average heat flux, RCS temperatures, RCS pressure, SG pressure, and various reactivity versus time.

The S-RELAP5 plant simulation results from the analysis of the Excess Load event were used as input into the MDNBR calculations. The plant simulations were adjusted to account for power, temperature, pressure, and flow measurement uncertainties in the MDNBR calculations. The MDNBR was above the NRC-approved DNB correlation 95/95 limit plus a 2% mixed core penalty. The peak LHGR is less than the LHGR FCM safety limit. The fuel centerline temperature for the HZP event is well below that required to melt fuel.

The radiological consequence of stuck open atmospheric dump and turbine bypass valves during an Excess Load event is less adverse than the Loss of Non-

Emergency AC Power event. Since non-emergency AC power is still available in the Excess Load event, steam may be directed to the condenser after 10 minutes for controlled plant cooldown. When this happens, the steam (and any activity in it) is no longer being released directly to the atmosphere through the atmospheric dump valves and MSSVs.

EOC cases at HZP and HFP were also evaluated for long-term subcriticality assuming single active failure of either a HPSI or MSIV. A return-to-power is predicted for cases assuming failure of a MSIV to close. The return-to-power peak power does not result in a power excursion that challenges the fuel SAFDLs.

14.4.4 CONCLUSION

The analysis of the Excess Load event demonstrates that the action of the RPS in conjunction with the initial margins maintained by the LCOs prevents exceeding the fuel SAFDLs. The RCS pressure upset limit is not exceeded since the RCS pressure decreases during the event. The radiological consequence of the stuck open atmospheric dump and turbine bypass valves during the event is a site boundary dose that is negligible compared to the 10 CFR 50.67 guidelines. The MTC is the only key parameter which is adversely impacted by extended burnup. The negative reactivity inserted due to the CEAs and boron injected via the HPSI pumps is sufficient to arrest the return-to-power shortly after turnaround.

14.4.5 REFERENCES

1. EMF-2310(P)(A), Revision 1, SRP Chapter 15 Non-LOCA Methodology for Pressurized Water Reactors, May 2004

TABLE 14.4-1
INITIAL CONDITIONS AND INPUT PARAMETERS TO DETERMINE APPROACH TO SAFDLs FOR THE EXCESS LOAD EVENT

PARAMETER	UNITS	HFP VALUE	HZP VALUE
Initial Core Power	MWt	2754	2.737×10^{-6}
Initial Core Inlet Temperature	°F	548	532
Initial RCS Pressure	psia	2250	2250
Initial Vessel Flow Rate	gpm	370,000	370,000
Effective MTC	pcm/°F	-5 to -33	-33
Minimum CEA Worth Available at Trip	pcm	5277.6	3500
EOC Kinetics, β_{eff}	---	0.005237	0.005237
ASI for MDNBR (Limiting Design Axial Profile)	---	-0.3	-0.3
Doppler Temperature Coefficient	pcm/°F	-1.1	-1.1
VHP Trip Setpoint	% RTP	112.0	40.0
VHP Trip Delay	sec	0.4	0.4
Temperature Shadowing or Decalibration Factor	%/°F	0.70	0.70
Resistance Temperature Detector Response Time, Hot/Cold	sec	0/12	Not Credited
Atmospheric Dump Valve Capacity (2 Valves)	10^6 lbm/hr	0.2925/valve	0.2925/valve
Turbine Bypass Valve Capacity (4 Valves)	10^6 lbm/hr	1.173/valve	1.173/valve
Maximum Predicted FQ	---	---	9.7

TABLE 14.4-2

SEQUENCE OF EVENTS FOR THE ZERO POWER EXCESS LOAD CONDITIONS TO CALCULATE MAXIMUM LHR

TIME (sec)	EVENT	SETPOINT OR VALUE
0.00	Turbine Admission Valve Opens	120% of Full Power Steam Flow
18.19	VHPT Setpoint Reached	40% of full power
18.25	Maximum Neutron Power	82.4% RTP
18.58	Trip Breakers Open	---
19.07	CEAs Begin to Drop into Core	---
20.17	MDNBR	> DNB Limit
20.17	Maximum Clad Surface Heat Flux	575.8 MWt
21.3	Maximum Fuel Centerline Temperature	< CTM Limit
22.1	CEAs Fully Inserted	---

TABLE 14.4-3

SEQUENCE OF EVENTS FOR APPROACH TO SAFDLs FOR THE FULL POWER EXCESS LOAD EVENT

TIME (sec)	EVENT	SETPOINT OR VALUE
0.0	Complete Opening of Dump and Bypass Valves at Full Power. Turbine Control Valves move to fully open position.	---
24.79	VHPT Setpoint Reached	112% of full power
25.19	Trip Breakers Open	---
25.6	MDNBR	> DNB Limit
25.67	CEAs Begin to Drop into Core	---
25.7	Peak Neutron Power	121.62% RTP
25.7	Maximum Clad Surface Heat Flux	3285.5 MWt