14.12 ASYMMETRIC STEAM GENERATOR EVENT

14.12.1 IDENTIFICATION OF EVENT AND CAUSE

The primary function of the SGs is to remove heat from the RCS. Any perturbation within the SGs will affect the RCS due to the close coupling of both systems.

An Asymmetric SG event is defined as any initiator that affects only one of the two SGs. A loss of load, an excess load, a LOFW, or an excess feedwater to only one SG would result in an Asymmetric SG event.

Asymmetric SG events, which are the result of a malfunction of one SG, cause a non-uniform core inlet temperature distribution. The non-uniform core inlet temperature distribution in conjunction with the moderator temperature reactivity feedback produces asymmetric local power peaking in the core.

The most limiting Asymmetric SG event is a loss of load to one SG. An asymmetric loss of load would produce the largest core inlet temperature differential across the core. Based on a negative MTC, the RCS temperature tilt across the core will cause an increase in local core power peaking and an approach to the fuel SAFDLs.

14.12.2 SEQUENCE OF EVENTS

An Asymmetric SG event can approach the DNBR and LHGR SAFDLs. The action of the Asymmetric Steam Generator Protection Trip (ASGPT), and the Low SG Pressure, Low SG Level, TM/LP, and HPTs will prevent exceeding these limits. The primary trip for the most adverse Asymmetric SG event is the ASGPT. The RCS Pressure Upset Limits will not be approached during the event. Since no fuel pin failures are postulated to occur, the site boundary dose criteria in 10 CFR 50.67 guidelines will not be approached.

14.12.2.1 Asymmetric Excess Feedwater

An Asymmetric Excess Feedwater event is initiated at HFP from within the LCOs by a malfunction in one of the feedwater controllers, which instantaneously fully opens the feedwater regulator valve to one SG. The full opening of the feedwater regulator valve causes additional subcooled feedwater to enter the SG which lowers the temperature and pressure. The result is a reduction in the steam flow from the affected SG. The excess feedwater also causes the affected SG cold leg temperature to decrease because additional heat is being extracted.

The analysis assumes the turbine demand remains constant, which causes the unaffected SG to pick up part of the load by further opening the turbine control valve. Present operating practices maintain the turbine control valve flow area constant, thus avoiding the increased demand. The increased steaming rate results in lowering the temperature of the SG and therefore the cold leg temperatures.

The result of the asymmetric decrease in the core inlet temperature is a temperature and power tilt across the core. Since the increased feedwater flow rate only decreases the temperature slightly, there will be a small increase in radial peaks and core power. The event will be terminated by the ASGPT. This event is less limiting than a loss of load to one SG (Section 14.12.2.4) because it produces a smaller temperature tilt across the core.

14.12.2.2 Asymmetric Loss of Feedwater

An Asymmetric LOFW event is initiated at HFP from within the LCOs by a malfunction in one of the feedwater controllers which instantaneously shuts the

feedwater regulator valve to one SG. The closure of the feedwater regulator valve causes a LOFW to the SG. The LOFW will cause the temperature and pressure to increase in response to the decreasing SG level. The temperature and pressure in the unaffected SG (i.e., with feedwater flow available) also increases in response to the increased turbine header pressure. The core inlet temperature from both SGs will increase with the decreased secondary heat transfer. A slight core inlet temperature asymmetry occurs with the higher inlet temperature resulting from the affected SG.

The small core inlet temperature tilt will not cause a significant radial power tilt. The slight increase in core temperatures in conjunction with a negative MTC will result in a decrease in core average power. The event will be terminated by the Asymmetric SG Pressure Trip or a Low SG Level Trip. This event is less limiting than a loss of load to one SG (Section 14.12.2.4) because it produces a smaller temperature tilt across the core.

14.12.2.3 Asymmetric Excess Load

An Asymmetric Excess Load event is initiated at HFP from within the LCOs by the inadvertent opening of a single secondary safety valve on one SG. The excess load on a single SG causes its pressure and temperature to decrease which results in a decrease in the core inlet temperature. Since the temperature from only one SG decreases, a core inlet temperature distribution tilt occurs across the core. In the presence of a negative MTC, positive moderator reactivity feedback occurs that increases the core power. A new steady-state condition is obtained once the core power increases to match the excess load demand. The event will be terminated by the Asymmetric SG Pressure Trip or Low SG Level Trip. This event is less limiting than a loss of load to one SG (Section 14.12.2.4) because it produces a smaller temperature tilt across the core.

14.12.2.4 Asymmetric Loss of Load

An Asymmetric Loss of Load event is initiated at HFP from within the LCOs by an inadvertent closure of a single MSIV on one SG. The loss of load to a single SG causes the pressure and temperature on the SG to increase. With the decrease in SG heat transfer, the core inlet temperature from the isolated SG will increase. The isolated SG water level drops rapidly as the increasing pressure collapses the steam bubble in the liquid inventory. The pressure will continue to increase until the MSSVs open.

The analysis assumes the turbine load demand remains constant, which causes the turbine control valves to open further. The increased load demand will decrease the other (i.e., unaffected) SG pressure and temperature. In response to the decreased temperature, the core inlet temperature from the SG will also decrease. Present operating practice maintains the turbine control valve flow area constant, which will lessen the severity of the event.

The result of the outlet temperature increase and decrease from their respective SGs is a severe core inlet temperature maldistribution. In the presence of negative MTC and FTC (normally negative at power), the coolant temperature tilt will cause a radial power shift toward the cold side of the core. The power in the outermost fuel bundles, where there is almost no mixing of the inlet flow, will experience the greatest local power increase. The power on the hot side of the core will decrease due to the negative moderator reactivity feedback.

The ASGPT will initiate a reactor trip to terminate the event when the absolute differential SG pressure (i.e., P_{sg1}-P_{sg2}) exceeds a preselected analysis setpoint value.

14.12.3 CORE AND SYSTEM PERFORMANCE

14.12.3.1 Mathematical Models

The transient response of the RCS and steam systems to the Asymmetric Steam Generator Loss of Load event was simulated using the S-RELAP5 thermal-hydraulic system code consistent with the methodology in Reference 1. The event is analyzed with an S-RELAP5 model which captures the asymmetric core inlet temperature distribution and applies local peaking augmentation factors (Reference 2).

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. 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. Both of these computer codes are described in Section 14.1.4.1.

14.12.3.2 Input Parameters and Initial Conditions

The input parameters and initial conditions used in the analysis of the Asymmetric Loss of Load event are listed in Table 14.12-1 and Figure 14.12-1. Those parameters that are unique to the analyses are discussed below.

The analysis used the radial peaking distortion factor as a function of core inlet temperature for calculating the minimum DNBR and peak linear heat generation rate (PLHGR). To increase the power tilt, a negative MTC was assumed. During a severe asymmetric transient, the cooler core inlet temperature and the temperature tilt decalibrate the neutron power and the DT power, respectively.

Asymmetric tube plugging is bounded by assuming no tube plugging in both generators and minimum MSSV setpoints. No tube plugging increases the initial pressures in both generators and causes earlier opening of the affected SGs MSSVs, thereby delaying actuation of the ASGPT.

The MTC is the only key parameter which is adversely impacted by extended burnup. The analysis assumed an EOC MTC value. Hence, the effects of extended burnup have been explicitly and conservatively included in the analysis.

14.12.3.3 Results

Table 14.12-2 contains the sequence of events for the Asymmetric Loss of Load event at HFP. Figures 14.12-2 through 14.12-6 present the transient behavior of the core power, core average heat flux, RCS temperatures, pressurizer pressure, and SG pressure.

The Asymmetric Loss of Load event at HFP conditions peak power result combined with the Technical Specification peaking factor, inlet temperature augmentation and uncertainties, and accounting for control rod position, axial peak, and engineering uncertainty, results in a conservative PLHGR that is below the cycle specific limit and is below the LHGR limit imposed in Reference 2.

The S-RELAP5 plant simulation results from the analysis of the Asymmetric SG Loss of Load event were used as input into the minimum DNBR calculations. The plant simulations were adjusted to account for power, temperature, pressure, and flow measurement uncertainties in the minimum DNBR calculations. The MDNBR was above the NRC-approved DNB correlation upper 95/95 limit plus a 2% mixed core penalty. In addition, adequate FCM margin exists for this event.

14.12.4 CONCLUSION

The analysis of the Asymmetric SG event demonstrates that operating within the LCOs in conjunction with the LSSS will prevent exceeding the fuel SAFDLs, and maintain the integrity of the RCS. The radiological consequence of opening the atmospheric dump valve upon reactor trip is a site boundary dose that is negligible compared to the 10 CFR 50.67 guidelines.

14.12.5 REFERENCES

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

2. Letter from Mr. D. V. Pickett (NRC) to Mr. G. H. Gellrich (CCNPP), dated February 18, 2011, Calvert Cliffs Nuclear Power Plant, Unit Nos. 1 and 2 - Amendment Re: Transition from Westinghouse Nuclear Fuel to AREVA Nuclear Fuel (TAC Nos. ME2831 and ME2832)

TABLE 14.12-1

INITIAL CONDITIONS AND INPUT PARAMETERS FOR THE LOSS OF LOAD TO ONE STEAM GENERATOR

PARAMETER	UNITS	VALUE
Initial Core Power	MWt	2754
Initial Core Inlet Temperature	°F	548
Initial RCS Pressure	psia	2250
Effective MTC	pcm/°F	-33
Fuel Doppler Temperature Feedback	---	EOC Fuel Temperature Dependent
ASGPT Setpoint	psid	186
Minimum CEA Worth Available at Trip	pcm	5740.8
SG Tube Plugging	%	0
Asymmetry in SG Tube Plugging Assumed	% difference between SGs	0
Initial Vessel Flow Rate	gpm	370,000

TABLE 14.12-2

SEQUENCE OF EVENTS FOR THE LOSS OF LOAD TO ONE STEAM GENERATOR

TIME (sec)	EVENT	VALUE
0.0	Spurious closure of MSIV on SG-1	---
0.0	Steam flow from unaffected SG increases to maintain turbine power	---
6.04	ASGPT Analysis Setpoint reached (differential pressure)	186.0 psid
6.94	Trip breakers open	---
7.44	CEAs begin to insert	---
Varies[a]	Minimum DNBR occurs	> 1.164

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[a] Near time of CEA insertion. Time depends on core conditions.