14.9 LOSS-OF-COOLANT FLOW EVENT

14.9.1 IDENTIFICATION OF EVENT AND CAUSE

The primary function of the RCPs is to provide forced coolant flow through the core. There are four RCPs in the RCS which are located in the SG cold legs. The RCS is a two-loop, two SG system with four cold legs.

Electrical power for the RCPs is provided from 13.8 kV ring busses which are connected to three service transformers. All three service transformers receive their power from the main switchyard which is arranged in a ring bus configuration. The power from each unit's main generator goes directly to the main switchyard and then comes back into the service transformers.

In the event that the main turbine-generator should trip, electrical power for the RCPs is provided by offsite sources through the ring bus. If a turbine trip occurs on Unit 2 during a period when offsite power sources are unavailable, the four RCPs would be initially energized by the transient output of the turbine-generator. During this period, the high rotational energy of the turbine-generator during initial stages of coast down is used to provide power to the RCPs. This turbine-generator coast down assist feature provides a slower decrease in RCS flow rate than would occur due to the influence of the RCP flywheels alone. Unit 1 does not have this assisted coast down feature and coasts down on the RCP flywheels. Should a failure occur in the service transformer, the affected pumps will coast down with their own flywheel energy. The turbine trip would result in a reactor trip. However, no credit is allowed for this trip in the analysis.

A Loss-of-Coolant Flow event is defined as a loss of forced reactor coolant through the core with offsite power available, but without a seized RCP rotor (Section 14.16). A loss-of-coolant flow with offsite power unavailable is discussed in Section 14.10.

The most limiting Loss-of-Coolant Flow event is a concurrent loss of power to all four RCPs. A loss of four RCPs is more limiting than a loss of one, two, or three RCPs as the coolant through the core will decrease faster with a loss of all four RCPs.

14.9.2 SEQUENCE OF EVENTS

A Loss-of-Coolant Flow event can approach the DNBR and LHGR SAFDLs and the RCS Pressure Upset Limit. The action of the low flow trip in conjunction with the steady-state margin ensured by the LCOs will prevent exceeding these limits. Since no fuel pin failures are postulated to occur, the site boundary dose criteria in 10 CFR 50.67 guidelines will not be approached.

A Loss-of-Coolant Flow event is initiated at HFP and within the LCOs by the concurrent loss of power to all four RCPs. The immediate system response to the coast down of the pumps is a rapid decrease in coolant mass flow rate through the core. In one second, the flow decreases by approximately 11% and in ten seconds, the flow is down to approximately 50% of full flow.

With the coolant mass flow rate decreasing, the core temperatures and the enthalpy rise across the core will start increasing. In the presence of a positive MTC that is normally negative, the increasing core temperatures will result in positive reactivity feedback. The core power will subsequently increase. Due to the fuel time constant and increased enthalpy, the core average heat flux will lag the core power rise.

Depending on the initial core flow measured by the SG differential pressure transmitters, the low flow analysis trip setpoint is reached in approximately one second. After sufficient time for trip signal processing and decay of the CEA holding coils (i.e., 1 second), the

CEAs begin to drop into the core and insert negative reactivity. Consequently, the increase in core power is terminated and starts to decrease. Since the core flow is still decreasing and the heat flux has not decreased, the DNBR will continue to decrease at this time. After the CEAs have been sufficiently inserted (depending on the axial power distribution) and taking into account the lagging heat flux, the DNBR transient will terminate within 3 to 5 seconds of the event.

Shortly after the core heat flux starts to decrease, the RCS temperatures and pressurizer pressure will begin to decrease. Since the loop cycle time is longer than the DNBR transient time (i.e., approximately 10 seconds compared to less than 5 seconds), the SG temperature and pressure remain essentially constant during the initial sequence of events. After the SDBS actuates, the system will stabilize to a HZP condition.

14.9.3 CORE AND SYSTEM PERFORMANCE

14.9.3.1 Mathematical Models

The transient response of the RCS and steam system to the Loss of Coolant Flow event was simulated using the S-RELAP5 thermal-hydraulic system code consistent with the methodology in Reference 1. The S-RELAP5 code is described in Section 14.1.4.1. The time-dependent coolant flow data was developed based on measured data for a zero plugged tube condition. The data was conservatively adjusted for the effect of SG tube plugging using the COAST computer code. The transient results were subsequently used as input for the evaluation of MDNBR using the XCOBRA-IIIC computer code. The code is described in Section 14.1.4.1.

14.9.3.2 Input Parameters and Initial Conditions

The input parameters and initial conditions used in the analysis are listed in Table 14.9-1. Those parameters which are unique to the analysis are discussed below.

The MTC and FTC are the only key parameters which are impacted by extended burnup. Since this transient is more limiting at BOC, corresponding MTC and FTC values were assumed in the analysis. Hence, extended burnup has no adverse impact on this event.

The coolant flow coast down calculated by S-RELAP5 was benchmarked to flow coast down data reflecting the effects of 10% SG tube plugging. Reactor trip for the Loss of Coolant Flow event was initiated by low coolant flow rate as determined by a reduction in the sum of the total loop flow. The plant protection system setpoint credited in the analysis was adjusted to account for uncertainties and time delays. The initiation of scram was delayed after the setpoint was reached to account for appropriate instrumentation and other time delays in the safety system including initiation of actual rod movement. The analysis is conducted at HFP BOC conditions, using a limiting axial power distribution. The BOC most-positive MTC Technical Specification value, independent of power level, and the BOC HFP nominal FTC (biased less negative) were used. The minimum transient DNBR is calculated using the most adverse DNBR initial conditions.

14.9.3.3 Results

Table 14.9-2 contains the sequence of events for the Loss-of-Coolant Flow event. Figures 14.9-2 through 14.9-5 present the transient core power, core average heat flux, RCS temperatures, and RCS pressure behavior.

Core boundary conditions from each case are used for the evaluation of the MDNBR, via the DNB LCO setpoint verification analysis (Reference 2). The MDNBR is above the NRC-approved DNB correlation upper 95/95 limit plus a 2% mixed core penalty.

The results show that the DNBR SAFDL is not exceeded. The peak RCS pressure scenario is bounded by the more limiting Feedline Break event.

14.9.4 CONCLUSION

The analysis of the Loss-of-Coolant Flow event demonstrates that the action of the RPS in conjunction with the LCOs will prevent exceeding the fuel SAFDLs and RCS Pressure Upset Limits. The radiological consequences of opening of the atmospheric dump valves upon reactor trip is a site boundary dose which is negligible compared to the 10 CFR 50.67 guidelines.

Since DNBR design limits are not exceeded and no fuel pins are predicted to fail, extended burnup has no adverse impact during this event.

14.9.5 REFERENCES

1. EMF-2310(P)(A), Revision 1, SRP Chapter Non-LOCA Methodology for Pressurized Water Reactors, May 2004
2. EMF-1961(P)(A), Statistical Setpoints for Combustion Engineering Type Reactors

TABLE 14.9-1

INITIAL CONDITIONS AND INPUT PARAMETERS FOR LOSS-OF-COOLANT FLOW EVENT

PARAMETER	UNITS	VALUE
Initial Core Power	MWt	2754
Initial Core Inlet Temperature	°F	548
Initial RCS Pressure	psia	2250
Initial Vessel Flow Rate	gpm	370,000
Minimum RCS Flow Trip Setpoint	% of 370,000 gpm	90
RCS Flow Trip Response Time	sec	0.5
Minimum CEA Worth Available at Trip	pcm	5277.6
Doppler Fuel Temperature Coefficient	pcm/°F	-0.8
Effective MTC	pcm/°F	+7
4-Pump RCS Flow Coast Down (Includes effects of 10% plugged tubes)	---	Figure 14.9-1

TABLE 14.9-2

SEQUENCE OF EVENTS FOR LOSS-OF-COOLANT FLOW EVENT

TIME (sec)	EVENT	VALUE
0.0	Loss of Power to all Four RCPs	---
0.91	Low Flow Trip Analysis Setpoint Reached	90% of 370,000 gpm
1.40	Trip Breakers Open	---
1.89	CEAs Begin to Drop Into Core	---
Various[a]	Minimum DNBR Occurs	> 1.164

(a) Less than 5 seconds. Time depends on axial shape.