14.11 CONTROL ELEMENT ASSEMBLY DROP EVENT

14.11.1 IDENTIFICATION OF EVENT AND CAUSE

The primary function of the CEA is to control the core axial power distribution and to provide instantaneous reactivity to shut down the reactor during controlled procedures and during abnormal and emergency conditions. Under normal operating conditions (i.e., controlled procedures), CEAs are inserted and withdrawn in a pre-programmed group sequence according to the PDIL curve in the Technical Specifications. There are 3 shutdown groups and 5 regulating groups for a total of 77 CEAs. Presently there are no PLCEAs (Chapter 3) in the core. The shutdown groups are dual CEAs (i.e., two CEAs with one extension shaft) and the regulating groups are single CEAs.

The CEAs are withdrawn, inserted, and held by the CEDMs which are located on top of the reactor vessel. The CEDM is a magnetic jack-type drive system which operates at a constant speed. A CEA is released from the CEDM holding coil grippers by removing the power to the holding coil. After approximately half a second, the CEDM holding coil magnetic flux will decay and the weight of the CEA and the CEA extension shaft will cause the CEA to drop into the core.

A CEA Drop event is defined as an uncontrolled insertion of a CEA. A loss of power to the CEDM holding coil or a mechanical fault in the CEDM magnetic jack drive will result in a CEA Drop event.

The most limiting CEA Drop event is an uncontrolled CEA insertion at HFP. Operation at HFP is most limiting as the reactor is then operating closest to the fuel SAFDLs. Appendix C of the Technical Specifications prohibits changing Core Operating Limits Report Figures 3.1.6, 3.2.3, and 3.2.5 until an NRC accepted generic, or Calvert Cliffs specific, basis is developed for analyzing this event at full power conditions only.

The CEA Drop event represents the limiting event with respect to challenging the LHGR FCM safety limit. The LHGR FCM safety limit that is imposed to compensate for the RODEX2 methodology, which does not explicitly model degraded fuel thermal conductivity, is 21 kW/ft (Reference 3).

14.11.2 SEQUENCE OF EVENTS

A CEA Drop event can approach the DNBR and LHGR SAFDLs. The steady-state margin ensured by the LCOs will prevent exceeding these limits. The RCS Pressure Upset Limit is not approached as the system cools down 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.

A CEA Drop event is initiated at HFP from within the LCOs by a failure of the CEDM holding coil. The immediate system response caused by the inserted negative reactivity worth is a reduction in the local core power in the vicinity of the dropped CEA. The local heat flux will be suppressed and the local moderator temperature will decrease. The azimuthal core power tilt will increase due to shutting down of part of the core. The core power and core average heat flux will correspondingly decrease. The amount of decrease is dependent on the dropped CEA worth.

The reduction in core average temperature, in conjunction with a negative moderator temperature (normally negative), will result in positive moderator feedback. The resulting positive reactivity addition from the moderator feedback partially compensates for Doppler and the dropped CEA negative reactivity.

The RCS pressure will decrease in response to the reduction in the core average temperatures. The analysis assumes the pressurizer pressure and level control systems, which would mitigate the pressure decrease, are inoperable. A decreased RCS pressure results in a lower minimum DNBR.

The decrease in core outlet temperature will cause the SG temperature and pressure to decrease. In the analysis, the turbine load is assumed to remain at full power. To maintain the same load, the turbine control valve is assumed to open further to compensate for the reduction in SG pressure. The result is an additional decrease in core inlet temperature and positive moderator feedback. Normal operating procedures maintain the turbine control valve at a set valve position which would prevent any further decrease in core inlet temperature. The cooldown of the RCS continues until the power mismatch between the RCS and the power demand is eliminated.

The core average temperature continues to decrease until sufficient positive moderator reactivity feedback offsets the Doppler and the dropped CEA negative reactivity and returns the core power to its pre-drop level. Consequently the power mismatch will be eliminated and no further cooldown of the RCS will occur. The RCS coolant temperatures will reach a new equilibrium value that is slightly lower than the initial values.

During the return to the initial core average power level and with part of the core power suppressed, the local power peaks will increase to make up the power difference. The local peaks that will occur are dependent upon the worth and position of the dropped CEA.

After detection of CEA drop/misalignment, the operator will initiate a power reduction as required by Technical Specifications.

14.11.3 CORE AND SYSTEM PERFORMANCE

14.11.3.1 Mathematical Models

The transient response of the reactor coolant and steam systems to the CEA Drop event was simulated using the S-RELAP5 thermal-hydraulic system code consistent with the methodology in Reference 1. The S-RELAP5 results were subsequently used as input for the evaluation of MDNBR and FCM. S-RELAP5 is described in Section 14.1.4.1.

14.11.3.2 Input Parameters and Initial Conditions

The input parameters and initial conditions used in the analysis are listed in Table 14.11-1. Those parameters that are unique to the analysis are discussed below.

The analysis assumes the most negative MTC and FTC of reactivity (including uncertainties), because these coefficients produce the minimum RCS coolant temperature decrease upon return to 100% power level and lead to a minimum DNBR.

Charging pumps and pressurizer heaters are assumed to be inoperable during the transient. This maximizes the pressure drop during the event. All other systems are assumed to be in manual mode of operation and have no impact on this event.

The analysis uses the maximum radial peaking distortion factors which, for conservatism, are the ratio of the post-drop to the pre-drop F_r. Calculations were performed to cover a range of dropped CEA worths from 10 pcm to 200 pcm. The

dropped CEA event is usually terminated by a TM/LP trip, a VHPT, or may potentially reach a new equilibrium state without trip.

As seen from the above discussion, the MTC and FTC are the only key parameters which are impacted by extended burnup. The analysis conservatively assumed an EOC MTC value of -3.3×10^{-4} $\Delta\rho/^{\circ}F$. In addition, the analysis assumed an EOC FTC value with an uncertainty and bias. Hence, the effects of extended burnup have been explicitly and conservatively included in the analysis.

The event was initiated by dropping a full-length CEA over a period of 3.0 seconds. The maximum increases in radial peaking factors in either rodded or unrodded planes were used in all axial regions of the core once the power returns to the initial level. The axial power shape in the hot channel is assumed to remain unchanged, therefore, the increase in the three-dimensional peak is proportional to the maximum increase in radial peaking factor. Since there is no trip assumed, and the secondary side continues to demand 100% power, the peaks will stabilize at these asymptotic values after a few minutes.

14.11.3.3 Results

Table 14.11-2 contains the sequence of events for the CEA Drop event at HFP. Figures 14.11-1 through 14.11-4 present the transient behavior of the core power, core average heat flux, RCS temperatures, and RCS pressure as a function of time for the 200 pcm case.

Core boundary conditions from each case are used for the evaluation of the MDNBR, via the DNB LCO setpoint verification analysis (Reference 2) and FCM. The resultant peak LHGR is less than the more limiting FCM LHGR limit provided by either Reference 3, or by cycle specific analysis, and the MDNBR is above the NRC-approved DNB correlation upper 95/95 limit plus a 2% mixed core penalty.

14.11.4 CONCLUSION

The analysis of the CEA Drop event demonstrates that operating within the LCOs will prevent exceeding the fuel SAFDLs, maintain the integrity of the RCS, and ensure negligible radiological release to the site boundary compared to 10 CFR 50.67 guidelines.

14.11.5 REFERENCES

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

2. EMF-1961(P)(A), Statistical Setpoints for Combustion Engineering Type Reactors

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

TABLE 14.11-1

INITIAL CONDITIONS AND INPUT PARAMETERS FOR CEA DROP 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
Effective MTC	pcm/°F	-33
Excore Detector Decalibration Factor	%/°F	0.70
Axial Power Distribution	ASI	-0.20 to +0.20
Maximum F_z	---	1.485
Distortion Factor (Full Power)	F_r post/ F_r pre	1.16

TABLE 14.11-2

SEQUENCE OF EVENTS FOR THE CEA DROP EVENT

TIME (sec)	EVENT	SETPOINT OR VALUE
0.0	Rod Drop Initiated	---
0.0	Core Heat Flux Reaches Minimum	---
3.0	CEA Fully Dropped	-200 pcm
3.0	Core Power Reaches Minimum	78.02% of RTP
300.0	MDNBR Boundary Conditions: Core Heat Flux Reaches Final Value	100.76% of RTP
	Core Inlet Temperature	542.14
	RCS Pressure	2214.1
	MDNBR[a]	> 1.164

[a] Results shown for the maximum dropped CEA worth. Core boundary condition from each dropped CEA case are used for the evaluation of MDNBR, via the setpoint verification analysis.