14.2 CONTROL ELEMENT ASSEMBLY WITHDRAWAL EVENT

14.2.1 IDENTIFICATION OF EVENT AND CAUSE

The CEAs, in a pre-programmed sequence (according to the PDIL), are used to control (dampen) xenon oscillations and rapidly control core power. The Regulating and Shutdown CEA Groups also provide the required negative reactivity for shutdown during DBEs.

The action of the control element assembly withdrawal (CEAW) Prohibit will stop the CEAs from withdrawing under the following conditions and, thus, prevent the CEAs from aggravating the situation.

a. High neutron flux power level pre-trip;
b. High rate of change pre-trip; or,
c. Thermal Margin/Low Pressure pre-trip.

The action of the CEA motion inhibit will prevent any CEA from being raised or lowered under the following conditions.

a. PDIL alarm;
b. CEA Regulating group out of sequence alarm; or,
c. CEA Regulating or Shutdown group deviation alarm.

Consequently, the CEA motion inhibit prevents the groups from being moved outside the pre-programmed sequence and prevents a single CEA from being misaligned. Therefore, only a sequential CEA group withdrawal needs to be addressed.

A CEAW event is defined as any event caused by a single malfunction in the Reactor Regulating System (RRS) or Control Element Drive Mechanism (CEDM) control system that results in a continuous sequential CEA group withdrawal. The CEA position indication systems are programmed to produce no more than a 40% overlap between CEA Regulating groups with Group 1 being withdrawn first and Group 5 last.

The results of the analysis are presented in Section 14.2.4.

14.2.2 SEQUENCE OF EVENTS

A CEAW event can approach the DNBR and linear heat generation rate (LHGR) SAFDLs and the RCS Pressure Upset Limit. Initial margins maintained by the LCOs in conjunction with the RPS (VHPT, TM/LP trip, or LPD trip) ensure that these design limits will not be exceeded. Since no pin failures are postulated to occur, the site boundary dose criteria in 10 CFR 50.67 guidelines will not be approached.

HFP and HZP conditions were analyzed based upon the assertion that the range of initial reactor power levels is bounded by analyzing only full-power cases due to the VHPT setpoint automatically resetting to track the current operating power level, resulting in a proportionately lower setpoint for a part-power case than for a full power case. The NRC asserts that the possible transient variations in the core power distribution may lead to a more limiting DNBR at lower power levels. The response to this concern incorporated an explicit analysis of part-power transients using an operating envelope that bounded Calvert Cliffs. However, the analysis did not provide a Calvert Cliffs specific basis to conclude that changes in the core operating limits are acceptable with respect to the part-power transient. Therefore, a licensing condition is imposed in the Technical

Specifications to restrict certain Core Operating Limits Report limits from being changed without prior NRC review and approval until an NRC-accepted, or Calvert Cliffs specific, basis is developed for analyzing the CEAW event at full power conditions only (Reference 3).

14.2.2.1 Zero Power Case

The zero power case is assumed to initiate at a HZP, critical condition. For events with high reactivity insertion rates, the positive reactivity insertion caused by CEA withdrawal will cause power to increase at an exponential rate. Since the event initiates at zero power with no heat being produced in the fuel, the heat flux will also be zero. If the reactor power goes above 10^{-4}% of rated power and the rate of change of neutron flux is greater than 1.5 decades per minute, a CEAW Prohibit will be initiated. If the rate exceeds 2.6 decades per minute, with the power between 10^{-4} and 15% of rated power, a reactor trip will be initiated. For conservatism, no credit for the High Rate-of-Change of Power Trip is taken in the analysis presented, i.e., for an event that initiates from a critical condition. However, the high rate-of-change of power trip is credited as justification for not analyzing subcritical CEAW events.

By the time core power reaches 1% of rated power, the neutron flux will be increasing exponentially at an extremely high rate. Although the reactor trip occurs at the minimum setting on the VHPT (30%; analysis assumes 36.4%), the core power could peak above 100% power depending on the worth of the CEAs. The core power peaks after trip due to the RPS electronic and the CEA holding coil delays, and the time necessary to insert enough SCRAM reactivity to offset the positive reactivity insertion. As core power increases, the fuel temperature will increase and result in Doppler feedback, which will reduce the peak core power. Due to the fuel time constant, the core heat flux will lag the core power and consequently result in a lower peak. The core power will rapidly decrease as the CEAs are inserted, thus terminating the power excursion.

The core average temperature will slowly increase as it follows the increase in core heat flux. Due to the loop cycle time, the core inlet temperature will lag the average temperature. With the exit temperature increasing faster than the inlet temperature, more moderator feedback will occur in the top portion of the core. Since the MTC is generally negative, more negative reactivity will be inserted in the top portion of the core resulting in the power peak going to the bottom of the core. For conservatism in the analyses, a positive MTC is used thereby adding positive reactivity.

During the event, the RCS pressure will increase and follow the core average temperature rise. Depending on the CEA worth, the temperature rise could increase the pressurizer pressure above the power-operated relief valve (PORV) setting. The action of the pressurizer pressure and level control systems will moderate the pressure peak. For peak pressure consideration, no credit is allowed for these systems.

The PORVs act to decrease primary pressure, resulting in more adverse DNBR consequences. The peak primary system pressure is not explicitly calculated. It is expected to be benign due to the MSSVs being available in Mode 3 and higher, and in Modes 1 and 2, the secondary system is available for heat removal until after reactor trip.

The SG temperature and pressure will increase as the core temperature increases. Upon the reactor trip, the atmospheric dump and steam bypass valves

will normally modulate the core average temperature and SG pressure to 532°F and below 900 psia, respectively. With the quick opening of the valves, the core inlet temperature will initially decrease and then follow core average temperature.

14.2.2.2 Full Power Case

The full power case is initiated at 100% of rated power and at the LCOs. As the CEAs are withdrawn at the preprogrammed rate, the core power will steadily increase at a rate dependent on the worth of the CEAs. If the CEAs are being withdrawn from a high worth region (i.e., a region in which the CEAs are suppressing the power), the core power will increase at a fast rate. Conversely, if the CEAs were initially in a low worth region, the power will increase at a slow rate.

The withdrawal of CEAs will cause the axial power distribution to shift to the top of the core. The associated increase in the axial peak is compensated by a decrease in the integrated radial peaking factor. The magnitude of the 3-D peak change depends primarily on the initial CEA configuration and the initial axial power distribution.

The withdrawal of CEAs will also cause the neutron flux power measured by the excore detectors to be decalibrated due to rod shadowing. This decalibration of excore detectors, however, is partially compensated for by neutron attenuation due to moderator density changes (temperature shadowing).

As the core power increases, the fuel temperature will increase and result in negative Doppler reactivity feedback. The core average heat flux will slowly increase and lag the core power at an increment dependent on the clad-fuel gap conductance. With the heat flux increasing, the core average temperature will increase. With the core average temperature increasing, the moderator feedback will increase or decrease the rate of reactivity addition depending on whether the MTC is positive or negative. As a result of the increase in core average temperature, the RCS pressure will increase. If the CEAs are fully withdrawn before any trip is reached, a new steady-state at a higher core power and core average temperature will result. With the turbine still demanding 100% of rated power, the atmospheric dump and bypass systems will pick up the additional power (load).

Assuming a large enough withdrawn CEA worth, a trip will occur on either the Variable High Power, Axial Flux Offset, TM/LP, or High Pressurizer Pressure Trips. The amount of withdrawn CEA worth to cause a trip depends on the MTC, Doppler coefficient, and the position of the CEAs.

During a CEAW with the fuel and the RCS heating up, the MTC (usually negative during power operation) and the Doppler coefficient (always negative during power operation) will offset part of the withdrawn CEA worth. With the RCS temperature increasing, the pressurizer pressure and the level will increase. Although no credit is taken in the analysis, the pressurizer sprays will partially suppress the pressure increase and the level control system will maintain the programmed level. For cases where the pressurizer pressure exceeds 2400 psia, a reactor trip will be initiated and the PORVs will open, thereby reducing the number of times the PSVs are actuated. For peak pressure consideration, the PORVs are assumed to be inoperable as they are non-safety grade. In addition, no credit is allowed for the action of the atmospheric dump and turbine bypass valves which would normally maintain the SG below 900 psia and regulate the average RCS temperature at 532°F.

When addressing the fuel DNB SAFDLs, the pressurizer sprays and PORVs are assumed operable to minimize system pressure. These systems act to maximize the margin required to account for transient shifts, which are necessary due to lack of dynamic compensation in the TM/LP trip. Transient shifts account for changes in monitored parameters that occur between the time a TM/LP trip pressure is sensed and the time of MDNBR.

14.2.3 CORE AND SYSTEM PERFORMANCE

14.2.3.1 Mathematical Models

The transient response of the RCS and steam systems to the CEAW event was simulated using the S-RELAP5 thermal-hydraulic system code, described in Section 14.1.4.1, consistent with the methodology in Reference 2. The XCOBRA-IIIC fuel assembly thermal-hydraulic code, described in Section 14.1.4.1, 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 NRC-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.

14.2.3.2 Input Parameters and Initial Conditions

The input parameters and initial conditions used in the analysis are listed in Table 14.2-1. Those parameters that are unique to the analysis are discussed below.

For DNB cases, reactivity parameters were chosen such that a new steady-state power level was reached at the VHPT setpoint to maximize DNBR degradation. For FCM cases, reactivity parameters were set to ensure the greatest power excursion and maximum peak FCM.

The key parameters for the CEAW event initiated from both HFP and HZP for determining minimum DNBR are the reactivity insertion rate due to rod motion, the MTC and the FTC. The maximum CEAW rate is calculated by combining the maximum CEA differential worth ($\Delta\rho$/inch) and the maximum CEAW speed of 30 in/min. The minimum transient DNBR is calculated using the most adverse DNBR initial conditions. The analysis conservatively assumed a positive MTC value since this, in combination with increasing coolant temperatures, inserts a positive reactivity and thus maximizes the power and heat flux transients. The analysis also assumed a BOC FTC with uncertainty. This, in combination with increasing fuel temperatures, inserts the least amount of negative reactivity due to Doppler feedback. This minimizes the transient minimum DNBR.

For HZP conditions, the scram worth of the CEAs is set to the Technical Specification minimum shutdown margin, which is more limiting than assuming that the highest-worth CEA is stuck in the fully withdrawn position.

The initial power level used for the analysis is the lowest following an extended shutdown (assumed to be 10^{-9} times the rated power). The analysis assumes that the event is preceded by an extended shutdown because the extremely low neutron population under such a condition delays the power increase as the CEAs are withdrawn until a significant amount of positive reactivity has been added, which maximizes the subsequent power excursion. The combination of the highest reactivity addition rate and the lowest initial power level produces the

highest peak values of the fuel rod surface heat flux and centerline temperature, which result in limiting DNB and FCM values.

The VHPT setpoint is further decalibrated by a factor that accounts for changes in the peripheral power that may occur as CEAs are withdrawn from the interior of the core.

For HFP conditions, a spectrum of positive insertion rates is analyzed from very slow to fast, limited only by bank worth and maximum drive speed. Two reactivity feedback matrices of cases are evaluated: for most-positive reactivity feedback (most-positive MTC and least-negative Doppler coefficient) and the other for most-negative feedback (most-negative MTC and most-negative Doppler coefficient).

For both matrices of reactivity feedback cases, reactivity insertion rate ranges bounding the respective lowest MDNBR point and the maximum value for CEA bank withdrawal are considered. The lower bound of the reactivity insertion rate range analyzed is also considered to be bounding of a reasonable minimum reactivity insertion rate for bounding Mode 1 Boron Dilution.

Protection against violation of the SAFDLs is provided by the VHPT or the TM/LP trip in the analysis.

14.2.3.3 Results

Table 14.2-2 contains the sequence of events for the zero power case for the maximum withdrawal rate. Figures 14.2-1 through 14.2-4 present the transient behavior of the core power, core average heat flux, RCS temperatures, and RCS pressure as a function of time. Also, the analysis revealed that the fuel centerline temperatures are well below those corresponding to the acceptable FCM limit provided in the Technical Specifications.

Table 14.2-3 contains the sequence of events for the full power case for the limiting withdrawal case with respect to DNBR SAFDL. Figures 14.2-5 to 14.2-8 present the transient behavior of the core power, core average heat flux, RCS temperatures, and RCS pressure as a function of time for this case. The limiting case is a CEAW from EOC HFP conditions with a withdrawal rate of 7.55 pcm/second. The analysis also concluded that the fuel centerline temperatures are well below those corresponding to the acceptable FCM limit.

The S-RELAP5 plant simulation results from the analysis of the CEAW event were used as input into the MDNBR calculations. The S-RELAP5 plant simulation was adjusted to account for power uncertainty. The temperature, pressure, and flow measurement uncertainties are accounted for in the MDNBR calculations. The MDNBR was above the high thermal performance DNB correlation upper 95/95 limit plus a 2% mixed core penalty for both the zero and full power cases.

The FCM calculation for the HZP case results in a fuel centerline temperature that is significantly less than the melt temperature provided in the Technical Specifications. The HFP case results in LHGR less than the LHGR FCM safety limit.

The CEAW event is not limiting with respect to peak RCS pressure. With no loss of secondary load or feedwater and no loss of offsite power, a reactor trip on VHPT or high pressurizer pressure, along with primary safety valve capacity, is sufficient to maintain peak RCS pressure well below the over pressurization limit.

Other events, such as Loss of Load, Loss of Normal Feedwater and Feedline Break, all exceed this event with respect to peak RCS pressure.

The radiological consequences of opening the atmospheric dump valve during the most adverse CEAW event is less adverse than the LOAC event.

14.2.4 CONCLUSIONS

The analysis of the CEAW event demonstrates that the initial margin maintained by the LCOs in conjunction with the action of the RPS prevents exceeding the fuel SAFDLs and the RCS Pressure Upset Limit during an uncontrolled CEAW transient. The radiological consequences of opening the atmospheric dump valve upon reactor trip during the most limiting CEAW event is a site boundary dose, which is negligible compared to the 10 CFR 50.67 guidelines.

Since the DNBR and centerline temperature melt (CTM) design limits are not exceeded for this event and no fuel pins are predicted to fail, it is concluded that extended burnup has no adverse impact during this event.

14.2.5 REFERENCES

1. Deleted
2. EMF-2310(P)(A), Revision 1, “SRP Chapter 15 Non-LOCA Methodology for Pressurized Water Reactors,” May 2004
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 14.2-1

INITIAL CONDITIONS AND INPUT PARAMETERS - CEAW EVENT

HZP

PARAMETER	UNITS	HZP VALUE
Initial Core Power	MWt	2.737×10^{-6}
Initial Core Inlet Temperature	°F	532
Initial RCS Pressure	psia	2250
Initial Vessel Flow Rate	gpm	370,000
Combined Bank Differential Worth	pcm/inch	32.0
Bank Withdrawal Rate	inches/minute	30
Scram Worth	pcm	3500
VHP Trip Setpoint	%RTP	36.4
VHP Trip Delay	sec	0.4
MTC	pcm/°F	+7.0
Maximum Predicted FQ for HZP CEA Withdrawal	---	3.688
Rod Shadowing Power Decalibration	---	0.677

HFP

PARAMETER	UNITS	HFP VALUE
Initial Core Power	MWt	2754
Initial Core Inlet Temperature	°F	548
Initial RCS Pressure	psia	2250
Initial Vessel Flow Rate	gpm	370,000
Combined Bank Differential Worth	pcm/sec	0.0002 to 5.0 for positive feedback 3.00 to 8.00 for negative feedback
Scram Worth	pcm	5277.6
VHP Trip Setpoint	%RTP	110.33
VHP Trip Delay	sec	0.9
MTC	pcm/°F	+7.0 for positive feedback -33 for negative feedback
Doppler Temperature Coefficient	pcm/°F	-0.80 for positive feedback -1.85 for negative feedback

TABLE 14.2-2

SEQUENCE OF EVENTS FOR ZERO POWER CEAW EVENT

TIME (sec)	EVENT	VALUE
0.0	Bank Withdrawal Begins	16.0 pcm/sec
37.55	Core Power Reaches VHP Trip Setpoint	53.767 %RTP
37.95	Reactor Trip Signal Generated	80.3 %RTP
38.45	Control Rods Released	98.9 %RTP
38.55	Maximum Nuclear Power	99.5 %RTP
40.16	Maximum Heat Flux Power	1198.8 MWt 43.8 %RTP

TABLE 14.2-3

SEQUENCE OF EVENTS FOR FULL POWER CEAW EVENT

TIME (sec)	EVENT	VALUE
0.0	Bank Withdrawal Begins	---
109.06	Trip Setpoint Reached	---
109.73	Maximum Power	111.01 %RTP
109.96	Reactor Trip Signal Generated	TM/LP
110.32	Maximum Heat Flux Power	110.58 %RTP
110.46	Control Rods Released	TM/LP