14.16 SEIZED ROTOR EVENT

14.16.1 IDENTIFICATION OF EVENT AND CAUSE

The primary function of the RCPs is to provide forced coolant flow through the reactor 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.

The shaft seal system for the RCPs consists of three sets of four similar, rubbing face seals mounted in a cartridge, plus a fourth rubbing face, low pressure, vapor seal mounted on top of the cartridge.

Each of the four seals consists of a rotating tungsten carbide ring riding over a carbon graphite stationary face. The reactor coolant leaking into the seal cavity is forced through the seal water cooler by the auxiliary impeller where it is cooled with component cooling water. The seals are kept at approximately 145°F by maintaining a controlled flow of this cooled reactor coolant through the seal cartridge.

Each pump is equipped with renewable casing wear rings, four tandem mechanical face seals, and a self-aligning, water-lubricated bearing mounted above the pump impeller. Additional shaft support is provided by the pump motor bearings. The pump motor-driver and pump shaft are connected with a rigid coupling. The pump impeller and pump shaft are bolted and pinned together to allow differential thermal expansion. The pump and motor are furnished as a unit complete with an oil lift pump, oil cooler, seal water cooler, and instrumentation. The instrumentation will alert the operators to any incipient failures in the pump motors or seals.

Non-reverse rotation devices are provided on the pump motors to prevent the pump from windmilling in the reverse direction, and to limit backflow through a stopped pump from thereby bypassing the core.

A Seized Rotor event is defined as a complete seizure (i.e., binding) of a single RCP shaft. The seizure is postulated to occur due to a mechanical failure or a loss of component cooling to the pump shaft seals.

The most limiting Seized Rotor event is an instantaneous RCP shaft seizure at HFP. The reactor coolant flow through the core would be asymmetrically reduced to three pump flow as the result of a shaft seizure on one pump.

14.16.2 SEQUENCE OF EVENTS

A Seized Rotor event can result in an approach to the fuel SAFDLs, to the RCS Pressure Upset Limit, and to the site boundary dose criteria in 10 CFR 50.67 guidelines. The action of the LSSS in conjunction with the LCOs will limit the number of fuel pins that experience DNB for a short period of time.

A Seized Rotor event is initiated at HFP from within the LCOs by an instantaneous complete seizure of a single RCP shaft. The immediate system response is a rapid reduction to three pump flow. With the loss of one RCP, the core inlet flow is non-uniform. The core inlet flow from the cold leg of the seized pump shaft is reduced.

Due to the reduction in core flow, the core coolant temperatures up the core will increase. Assuming a positive MTC, the core power will increase. Normally, the MTC is negative at power which will start shutting down the core. The core average heat flux will decrease slightly due to the increasing core temperatures. After the RPS response time and CEA holding coil delay time has elapsed, the insertion of the CEAs will terminate the power rise. The heat flux will then be reduced to the decay heat level.

Assuming the event initiated at the most adverse DNBR condition in conjunction with an instantaneous RCP seized shaft, a limited number of fuel pins may experience DNB for a short period of time. Since the time of minimum DNBR occurs in less than two seconds, the events occurring on the secondary side (i.e., SG) will not affect the results.

14.16.3 CORE AND SYSTEM PERFORMANCE

14.16.3.1 Mathematical Models

The transient response of the RCS and steam systems to the Seized Rotor event was simulated using the S-RELAP5 thermal-hydraulic system code consistent with the methodology in Reference 5. 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 the 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 the simulation. Both of these computer codes are described in Section 14.1.4.1.

14.16.3.2 Input Parameters and Initial Conditions

The input parameters and initial conditions used in the analysis are listed in Table 14.16-1. Those parameters which are unique to the analysis are discussed below.

A three pump, core inlet, maldistribution factor is used in the analysis to account for reduced flow into the assemblies near the core inlet cold leg with the seized pump shaft. The three pump core mass flow rate is the total core flow assuming three pump operation. The analysis accounted for core bypass.

The asymmetric core inlet flow distribution dictated in Reference 6 is used to perform the Seized Rotor event analysis in accordance with the methodology described in Reference 5. The inlet flow factors are depicted in Reference 7.

Reactor trip for the Seized Rotor event was initiated by a low coolant flow trip. The RPS trip setpoint was adjusted to account for uncertainties and time delays. The initiation of scram was delayed after the setpoint was reached to account for time delays including initiation of control rod movement.

The key transient parameters, which are impacted by extended burnup, are MTC, FTC and radioisotope gap concentrations. The BOC most-positive MTC Technical Specification value independent of power level was used for this analysis. The event occurs quickly and is not sensitive to other neutronic parameters. The BOC HFP nominal fuel temperature coefficient (biased less negative) was used. In addition, the radioisotope gap concentrations assumed in calculating site boundary doses correspond to a burnup of 62,000 MWD/MT. Hence, extended burnup effects have been conservatively included in the analysis of this event.

14.16.3.3 Results

Table 14.16-2 contains the sequence of events for the Seized Rotor event. Figures 14.16-1 through 14.16-4 present the transient behavior of the core power, core average heat flux, RCS temperatures, and RCS pressure.

The S-RELAP5 plant simulation results from the analysis of the Seized Rotor event were used as input into minimum DNBR calculations. The plant simulation data were adjusted to account for power, temperature, pressure, and flow measurement uncertainties in the minimum DNBR calculations. The MDNBR was above the HTP DNB correlation upper 95/95 limit plus a 2% mixed core penalty. This event does not challenge the FCM SAFDL.

The potential for DNB propagation during the Seized Rotor event was not evaluated because no fuel rods are expected to experience DNB.

14.16.4 DOSE ANALYSIS

A Seized Rotor event is initiated at HFP by an instantaneous complete seizure of a single RCP shaft. With the reduction of core flow due to the loss of an RCP, the core coolant temperatures will increase. Assuming a positive MTC, the core power will increase. The core average heat flux will decrease slightly due to the increasing core temperatures. The insertion of the CEAs due to a low RCS flow trip will terminate the power rise; however, a maximum of 5% of fuel pins may experience DNB for a short period of time and are assumed to fail. The initial secondary activity, together with initial primary activity, and failed fuel activity released to the primary that then leaks into the secondary at the Technical Specification limit of 200 gpd, will escape out of the SGs via the ADVs and condenser. Note that per the requirements of Reference 4, the release of fission products from the secondary system should be evaluated with the assumption of a coincident LOOP. Thus, the use of condensers is not credited.

The Seized Rotor event dose analysis conforms to the regulatory requirements of 10 CFR 50.67 and Reference 4 using AST methodology.

For the 8-hour secondary release path scenario, the 16% I-131, 10% other iodines, 20% Kr-85, 10% other noble gases, and 24% alkali metals which are contained in the gas gaps of the fuel which experience clad failure, are released into the primary system, which is then transmitted into the secondary system via the Technical Specification SG tube leakage. Environmental releases occur from both SGs via the ADVs. The SG tubes remain covered for the duration of the event; therefore the gap iodines have a partition coefficient of 100 in the SGs. A conservative flashing fraction is assumed (10% for the first 15 minutes and 1% thereafter); however, no credit for scrubbing in the SG is assumed. The retention of particulate radionuclides in the SGs is limited by the moisture carryover from the SGs. A value of 0.001 was conservatively assumed. The steam release from the first 1800 seconds was taken directly from a CESEC analysis. The steam release from 1800 seconds to 8 hours is based on a simple energy balance methodology; that is, the steam released from 1800 seconds to 8 hours is based on the amount of steam required to remove the residual heat from the primary and secondary systems, the decay heat generated in the core, and the RCP heat. Radionuclide transport was modeled by the RADTRAD computer code.

The activity released to the environment is transported to the site boundary and to the Control Room via appropriate atmospheric dispersion coefficients. A constant Control Room inleakage of 3500 cfm was assumed in this work. Control Room filtration is credited based on a nominal flow of 10,000 $\pm$ 1,000 cfm per train. A charcoal filter efficiency of 90% is credited for elemental and organic iodine, while a HEPA efficiency of 99% is credited for particulate iodine. The Control Room and site boundary doses are calculated based on appropriate breathing rates and occupancy factors and on References 1 and 2 dose conversion factors. Additional inputs are included in Table 14.16-3.

The EAB, LPZ, and Control Room doses for the design-basis Seized Rotor event are detailed in the following table. Note that all values are below the regulatory limits.

Seized Rotor Event Results			
Results	EAB Rem	LPZ Rem	Control Room Rem
8 hour Secondary Pathway	0.041	0.0095	0.7885
Regulatory Limits	2.5 (Reference 4)	2.5 (Reference 4)	5.0 (Reference 3)

14.16.5 CONCLUSION

For the case of the Loss-of-Coolant Flow resulting from a seizure of a RCP shaft, the Low Flow Trip in conjunction with the DNB LCOs results in no fuel rod expected to experience DNB. For an assumed maximum failure of 5% of the fuel pins, the resultant site boundary doses are well within the 10 CFR 50.67 limits. In addition, the maximum RCS pressure experienced during the event is expected to be well below the upset pressure limit of 2750 psia.

The analysis of this event explicitly included the effects of extended burnup. Since the site boundary doses are within 10 CFR 50.67 limits, it is concluded that the consequences of the Seized Rotor event are acceptable at extended burnup. Departure from nucleate boiling propagation was not evaluated since no fuel pins are expected to experience DNB.

14.16.6 REFERENCES

1. Federal Guidance Report (FGR) 11, “Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion,” September 1988
2. Federal Guidance Report (FGR) 12, “External Exposure to Radionuclides in Air, Water, and Soil,” September 1993
3. 10 CFR 50.67, “Accident Source Term”
4. Regulatory Guide 1.183, “Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors,” July 2000
5. EMF-2310(P)(A), Revision 1, “SRP Chapter 15 Non-LOCA Methodology for Pressurized Water Reactors,” May 2004
6. Letter from Mr. D. V. Pickett (NRC) to Mr. G. H. Gellrich (CCNPP), “Calvert Cliffs Nuclear Power Plant, Units Nos. 1 and 2 - Amendment Re: Transition from Westinghouse Nuclear Fuel to AREVA Nuclear Fuel (TAC Nos. ME2831 and ME2832),” February 18, 2011
7. Letter from Mr. G. H. Gellrich (CCNPP) to Document Control Desk (NRC), “Supplement to the License Amendment Request: Transition from Westinghouse Nuclear Fuel to AREVA Nuclear Fuel,” December 30, 2010

TABLE 14.16-1

INITIAL CONDITIONS AND INPUT PARAMETERS FOR SEIZED ROTOR EVENT

PARAMETER	UNITS	VALUE
Initial Core Power Level	MWt	2754
Core Inlet Coolant Temperature	°F	548
4-Pump Vessel Mass Flow Rate	gpm	370,000
3-Pump Vessel Mass Flow Fraction	Frac. of 4-Pump	Approximately 0.75[a]
RCS Pressure	psia	2250
ASI (Range)	---	Top Peaked Design Axial
F_r	---	1.65

[a] As established by the S-RELAP5 initialization.

TABLE 14.16-2

SEQUENCE OF EVENTS FOR SEIZED ROTOR EVENT

TIME (sec)	EVENT	ANALYSIS SETPOINT OR VALUE
0.0	Seizure of One RCP	---
0.205	Low Coolant Flow Trip Analysis Setpoint is Reached	90% of Initial 4-Pump Flow
0.704	Trip Breakers Open	---
1.204	CEAs Begin to Drop Into Core	---
1.55	Minimum DNBR Occurs	> 1.164

TABLE 14.16-3

ASSUMPTIONS FOR SEIZED ROTOR DOSE CALCULATION

1. Initial thermal power is 2754 MWt.
2. The pin power peaking factor is 1.70.
3. The failed fuel fraction is 5%.
4. The damaged fuel rods are assumed to release their gas gap activities consisting of 16% I-131, 10% other iodines, 20% Kr-85, 10% other noble gases, and 24% alkali metals instantaneously and homogeneously throughout the primary system at the initiation of the accident. The primary Technical Specifications activities of 0.5 microCi/gram DEQ I-131 and 100/Ebar microCi/gram noble gas are assumed to be homogeneously distributed throughout the primary system at the beginning of the accident. The secondary Technical Specification activities of 0.1 microCi/gram DEQ I-131 are assumed to be homogeneously distributed throughout the secondary system at the beginning of the accident.
5. Iodine releases from the SGs to the environment are assumed to be 97% elemental and 3% organic.
6. The primary to secondary leakage of 200 gpd per Technical Specification 3.4.13 is assumed to continue until the primary system pressure is less than the secondary system pressure or until the temperature of the leakage is less than 100°C (212°F). The release of radioactivity is assumed to continue until SDC is in operation and releases from the SGs have been terminated. For the secondary system release pathway, the duration of the cooldown from HFP, defined as 574.5°F and 2250 psia to SDC, defined as 300°F and 270°psia per the EOPs, is assumed to be 8 hours.
7. The retention of particulate radionuclides in the SGs is limited by the moisture carryover from the SGs. A value of 0.001 was conservatively assumed.
8. The breathing rates and Control Room occupancy factors are per Reference 4.
    - Breathing rate:
        - 3.5E-4 m^3/s for 0-8 hours
        - 1.8E-4 m^3/s for 8-24 hours
        - 2.3E-4 m^3/s for 24-720 hours
    - Occupancy factors:
        - 1.0 for 0-24 hours
        - 0.6 for 24-96 hours
        - 0.4 for 96-720 hours
9. The ADV to site boundary 2-hour, atmospheric dispersion coefficient is 1.44E-4 sec/m^3.
10. The atmospheric dispersion coefficients from the ADV to the Control Room are:
    - 3.83E-3 sec/m^3 for 0-2 hours
    - 3.25E-3 sec/m^3 for 2-8 hours
    - 1.32E-3 sec/m^3 for 8-24 hours
    - 9.92E-4 sec/m^3 for 24-96 hours
    - 7.92E-4 sec/m^3 for 96-720 hours