Reactor Systems Reviewer Final Integrated Plan Checklist for Orders EA-12-049 and EA-12-051 Safety Evaluations

Boiling Water Reactors

Summary of Staff Conclusions for Boiling Water Reactors (BWRs):

- The NRC staff concludes that the licensee's analytical approach should appropriately determine the sequence of events (SOEs), including time-sensitive operator actions, and evaluate the equipment requirements, including pump sizing and cooling water capacity, for reactor core cooling to mitigate the analyzed extended loss of alternating current power (ELAP) event.
- The NRC staff concludes that the recirculation pump seal leakage rates assumed in the licensee's thermal-hydraulic analysis may be applied to the beyond-design-basis ELAP event for the site.
- The NRC staff concludes that, based on the analysis and SOEs, the licensee's strategy should maintain adequate core cooling for the analyzed ELAP event.
- The NRC staff concludes that the licensee's strategy should result in acceptable shutdown margin for the analyzed ELAP event. (This is based on BWR design.)
- The NRC staff concludes that the FLEX pumps should have adequate capacity and should be deployable in sufficient time to support core cooling and reactor coolant system (RCS) inventory control during the analyzed ELAP event.
- The NRC staff concludes that the water sources and FLEX pumps should be adequately protected and should have sufficient redundancy to support core cooling and RCS inventory control during the analyzed ELAP event, consistent with NEI 12-06.
- The NRC staff concludes that the licensee should have sufficient capacity of water on site and the ability to provide water of sufficient quality to support core cooling long-term for the analyzed ELAP event.

Note: {information which should be placed on the electronic portal is bracketed}

Safety Evaluation (SE) Section 3.2.3.2 (Thermal-Hydraulic Analyses)

1. Describe the analytical approach for determining the sequence of events (including the timing of operator actions and pump sizing) (River Bend Station, Unit 1 (River Bend) FIP Sections 2.3, 2.3.6, 2.3.7, 2.3.8)

    a. If using the Modular Accident Analysis Program (MAAP), provide appropriate answers to white paper (Ref. 1) questions and confirm adherence to limitations in NRC endorsement (Ref. 2) {EPRI Template filled out on e-portal}
    b. Confirm collapsed water level stays above top of the active fuel throughout the event {MAAP analysis on e-portal}
    c. Discuss assumptions concerning primary system leakage
        i. State assumption for pressure boundary leakage and justify if not using full TS leakage
        ii. State assumptions for Recirculation Pump leakage rate and basis

SE Section 3.2.1.2 (Phase 1)

1. Discuss Phase 1 RCS injection pumps and water sources (River Bend FIP Sections 2.3.1, 2.3.9)

    a. [If RCIC plant] Discuss the availability of water sources for the reactor core isolation cooling (RCIC) pump
        i. State whether the condensate storage tank is protected against all hazards
            1. Describe any analyses performed to demonstrate equipment is robust (e.g., if it is not originally designed to withstand all events) {analysis of robustness on e-portal if not originally robust}
        ii. Or state whether swap-over to torus is protected
    b. [If IC plant] Discuss the availability of water sources for the ICs
        i. Discuss robustness of tanks and pumps – are they robust for all hazards? {analysis of robustness on e-portal if not originally robust }
        ii. Discuss time to dryout versus time to supply makeup or alternate cooling {analysis of time to dryout, validation time to align alternate cooling }

SE Section 3.2.1.2 (Phase 2)

1. Discuss Phase 2 RCS injection pumps, water sources, and control of RCS injection (River Bend FIP Sections 2.3.2, 2.3.9)

    a. Time to align Phase 2
        i. State time available based on analysis / operator actions
            1. State any actions to maintain Phase 1 water sources or extend operation of RCIC (e.g., venting, align cool water sources) [This is coordinated with the Containment review.]
        ii. State time required to set up Phase 2
            1. {validation, procedure for aligning on e-portal}
    b. Primary and alternate connection points – state connection points (on diverse trains) (at least one robust for each hazard)
        i. Protection of pumps and suction / discharge flow paths
            1. {simplified diagrams showing diversity}
            2. {analysis showing robust if using plant equipment that is not originally designed to be protected}
    c. State the capacity of the Phase 2 pump (flow rate, pressure)
        i. Compare to required makeup capacity
    d. Discuss robustness of water sources
        i. Describe any analyses to demonstrate robustness (if not originally designed to be protected) {analysis on e-portal}
        ii. Include availability of diverse water sources even if not credited {hierarchy of water sources on e-portal}
    e. Discuss how operators control RCS water level (e.g., throttle flow, allow water flow out safety relief valves?)
        i. If using dirty water sources, state that plan would provide top-down cooling (e.g., fill above separators)

1. {Procedure for adjusting RCS level if necessary for top down cooling, Boiling Water Reactor Owners Group documentation does not support indefinite coping}

SE Section 3.2.1.3 (Phase 3)

1. Discuss the Phase 3 long term coping with pumps and water sources (River Bend FIP Sections 2.3.3, 2.3.9, 2.10)

    a. State whether Phase 3 pumps are backup for Phase 2 or would perform additional functions
        i. State capacity of Phase 3 pumps vs. required capacity
    b. Discuss long term sources of clean water
        i. State plans for water purification (e.g., use NSRC water purification)
        ii. State whether credited plan is to go on shutdown cooling

SE Section 3.2.3.1.2 (Plant instrumentation)

1. Provide a list of instrumentation used to control the event (e.g., NEI 12-06 instrumentation list, Ref. 3 or 4) (River Bend FIP Section 2.3.5)

    a. Discuss any deviations from NEI 12-06 list
    b. Confirm available / accessible throughout event
    c. Confirm availability of backup methods for taking readings locally

SE Section 3.1 (Overall Mitigating Strategy)

1. Summarize the sequence of events including the validation times, and the calculation times (River Bend FIP Sections 2.3.1, 2.3.2, 2.3.3, 2.17)

Pressurized Water Reactors

Summary of Staff Conclusions for Pressurized Water Reactors:

- The NRC staff concludes that the licensee's analytical approach should appropriately determine the SOEs, including time-sensitive operator actions, and evaluate the equipment requirements, including pump sizing and cooling water capacity, for reactor core cooling to mitigate the analyzed ELAP event.
- The NRC staff concludes that the RCP seal leakage rates assumed in the licensee's thermal-hydraulic analysis may be applied to the beyond-design basis ELAP event for the site.
- The NRC staff concludes that steam generator (SG) makeup should be supplied in time and should continue with sufficient capacity to provide continued RCS heat removal for the analyzed ELAP event.
- The NRC staff concludes that the licensee's plans should maintain natural circulation flow in the RCS for core heat removal (and boron mixing) for the analyzed ELAP event.
- The NRC staff concludes that the FLEX pumps should have adequate capacity and should be deployed in sufficient time to maintain SG and RCS inventory for the analyzed ELAP event.
- The NRC staff concludes that the licensee's strategy should provide adequate boron levels and boron mixing in the RCS to maintain acceptable shutdown margin for the analyzed ELAP event.
- The NRC staff concludes that the water sources and FLEX pumps should be adequately protected and should have sufficient redundancy to support core cooling and RCS inventory control during the analyzed ELAP event, consistent with NEI 12-06.
- The NRC staff concludes that the licensee should have sufficient capacity of water on site and the ability to provide water of sufficient quality to support core cooling long term for the analyzed ELAP event.

Note: {information which should be placed on the electronic portal is bracketed}
PWR Information needs:

FIP Sections are in green and typically refer to North Anna (PWR) pilot. Other FIPs are referenced where level of information was of high quality. (North Anna was generally acceptable for all sections except RCP seals. Issues with hydrothermal corrosion and the white paper on Flowserve were after the pilot was developed, so later licensees should include that information. Also, the North Anna FIP is silent on isolating accumulators because North Anna does not need to do it, so most licensees will need to add that information.)

Reactor Core Cooling Strategies – SE Section 3.2

SE Section 3.2.3.2 (Thermal-Hydraulic Analysis)

1. Describe the analytical approach for determining the sequence of events (including the timing of operator actions and pumps sizing) (North Anna FIP Sections 2.3.1, 2.3.7)

a) State the Code and method used (NOTRUMP, CENTS, plant-specific analysis with other codes, use of Owners Group analyses)
    i. Describe use of code according to white paper and staff review thereof (CENTS, NOTRUMP) {analysis}
    ii. For plants using NOTRUMP, discuss whether the plant parameters are bounded by the NOTRUMP generic parameters. If not provide justification for why it is ok. {paper comparing the NOTRUMP values to the plant values as asked for during audit, PWROG-14027 (Ref. 5) scaling analysis}
    iii. For plants using plant-specific analyses (e.g., RELAP, RETRAN-3D) discuss the code and the pedigree of the input deck (previous uses, benchmarks, etc. as appropriate) {analyses on e-portal}
    iv. For plants with Westinghouse-style RCP seals, discuss how the code-calculated time to entering reflux cooling is affected by hydrothermal corrosion of the RCP seal faceplates. (Catawba is one plant that addressed seal corrosion in their FIP (Attachment 7) – but the staff needed additional information for its review).

SE Section 3.2.3.3 (Reactor Coolant Pump Seals)

1. Discuss RCP seal leakage rate assumptions (North Anna FIP Section 2.3.8)

    a) Westinghouse plants with standard seals follow industry methodology, as modified by staff's review of special focus areas (see previously issued SEs), including hydrothermal corrosion
        i. Provide cooldown profile (time at temperature) in procedures (to permit staff evaluation of hydrothermal corrosion / leakage) (North Anny FIP Section 2.3.1, 2.3.2, 2.3.3 Note: to date this has been via supplements.)
    b) Plants with low leakage seals follow applicable white paper methodology (Westinghouse SHIELD or Flowserve N-Seal, Refs. 6 and 7), including demonstration of conformance with limitations and conditions, as well as those in the respective NRC endorsement letters (Refs. 8 and 9) (Palisades SE Section 2.3.8)
    c) Combustion Engineering plants (without low-leakage seals) follow RCP seal leakage white paper (Ref. 10) that is based on maximum leakage postulated for excess flow check valves.
    d) {Analysis of appropriate leakage rates if not following above}

SE Section 3.2.1.2 (RCS Makeup Strategy)

1. State the calculated time to loss of natural circulation (entry into reflux cooling / boiler-condenser cooling) in the absence of RCS makeup (North Anna FIP Section 2.3.7)

    a) {How transition to reflux cooling /boiler-condenser cooling was defined.}

2. Discuss preclusion of Nitrogen injection from accumulators / SITs / CFTs (North Anna FIP Sections 2.3.1, 2.3.7)

    a) SG depressurization setpoint (e.g., O.08, O.12, O.13, for Westinghouse plants) and how determined (calculation with the FLEX conditions accounted for, including

appropriate heat transfer and accounting for containment heatup of accumulators) {Analysis}

b) Cooldown time frame {Procedure for cooldown to the appropriate setpoint}
c) Timing of the ability to isolate the accumulators (can include in SOE Timeline – see McGuire FIP)

SE Section 3.2.3.4 (Shutdown Margin)

1. Discuss shutdown margin (North Anna FIP Sections 2.3.9, 2.3.10)

    a) Discuss overall strategy for injection, cooldown (including temperature hold points), and venting, including event timing {procedures}
    b) {Boron concentration needed to maintain shutdown margin as RCS temperature is reduced - analysis with justification for conservatisms or actual parameters used – confirm re-evaluated during reload analyses}
    c) Summary of compliance with boric acid mixing white paper (Ref. 11), including limitations and conditions in associated endorsement letter (Ref. 12)
    d) Credit for Xenon (if any)
    e) Time to start and complete boron injection (including 1 hour mixing time), with conservative assumptions on SIT injection {analysis}
    f) Need for RCS venting to support sufficient injection - Head vent is preferred over PZR PORV
        i. Ability to repower vent
        ii. Ability of vent to discharge sufficient volume
    g) Concentration and volume of borated water source
    h) {Ability of the FLEX pump to inject enough volume}
    i) Confirm minimum temperature in shutdown margin envelops minimum RCS temperature in mitigating strategy, particularly if entry into shutdown cooling mode is credited for demonstrating order compliance

SE Section 3.2.1.1 (Core Cooling Strategy)

1. [If plant needs to take local actions to initiate SG makeup or realign TDAFW to all SGs] Discuss time to SG dryout or overfilling {analysis – cover issues in a. above if different code than sequence of events} compared to time to align SG makeup / realign TDAFW to all SGs (Point Beach FIP Section 3.2.1.1)

2. [B&W plants] Discuss PZR level control and restoration of PZR heaters / inventory control to support B&W natural circulation (North Anna FIP Sections 2.3.1, 2.3.7)

    a) Describe cooldown time frame, makeup capability, timing of actions {Procedure maintains pressurizer level} {Procedure follows calculation done for B&W unit}

SE Section 3.2.1.1.1 and 3.2.1.2.1 (Phase 1)

1. Discuss Phase 1 equipment and actions (SG injection pumps, RCS makeup pumps (if used), pressurizer heaters (if used), water sources, and accumulator isolation). (North Anna FIP Sections 2.3.1, 2.3.4)

    a) Discuss the water source(s) for SG injection and RCS injection (if used)
        i. Discuss protection of tanks/water sources {analysis if not designed to withstand all hazards}
    b) Discuss the pumps used (TDAFW, DGAFW, or alternate SG injection; RCS makeup (if used))
        i. Discuss protection of pumps and piping {analysis showing robust if not originally protected }
    c) Discuss actions to preclude Nitrogen injection into the RCS (power and close accumulator isolation valves, open accumulator vent valves - containment entry should not be necessary to vent or isolate accumulators). {Procedure for isolation or venting of the accumulators} (Palisades FIP Section 2.3.4.26)
        i. Discuss protection of equipment to preclude Nitrogen injection
    d) Discuss actions to support shutdown margin (if any).

SE Section 3.2.1.1.2 and 3.2.1.2.2 (Phase 2)

1. Discuss Phase 2 equipment and actions (SG makeup and RCS injection pumps, water sources, and control of injection and cooling) (North Anna FIP Sections 2.3.2, 2.3.4, 2.3.5, 2.3.10, 2.9)

    a) Discuss RCS injection
        i. Time to deploy/align RCS injection (vs. the time to enter reflux cooling) {validation} {procedure}
            - Discuss whether time to reflux cooling or time to loss of SDM is bounding (need for RCS makeup or boration)
        ii. Primary and alternate flow paths (on diverse trains) (at least one robust for each hazard)
            - Protection of pumps and suction / discharge flow paths
                - {analysis showing robust if not originally protected}
            - {simplified diagrams showing diversity}
        iii. Provide flow rate(s)
        iv. Discuss water source(s)
            - Protection of water sources
                - {Analysis showing robust if not originally designed to withstand external events }
            - Hierarchy of water sources
            - How long water sources will last
    b) Discuss SG injection
        i. Time to deploy/align SG injection (vs. time required) {validation} {procedure}

ii. Primary and alternate flow paths (on diverse trains) (at least one robust for each hazard)
   - Protection of pumps and suction / discharge flow paths
      - {analysis showing robust if not originally protected}
   - {simplified diagrams showing diversity}

iii. Provide flow rate vs. required flow rate

iv. Discuss water source(s)
   - Protection of water sources
      - {Analysis showing robust if not originally designed to withstand external events }
   - Hierarchy of water sources
   - How long water sources will last

SE Section 3.2.1.1.3 and 3.2.1.2.3 (Phase 3)

1. Discuss the Phase 3 long term coping pumps and water sources (North Anna FIP Sections 2.3.3, 2.3.10, 2.10)

   a) Discuss use of Phase 3 equipment pumps
      i. Backup to Phase 2 equipment or additional uses (e.g., shutdown cooling)
      ii. Connection points
   b) Discuss the long term borated water strategy
      i. Discuss whether licensee requests NSRC Boration Skid, water purification, method for indefinite coping and production of borated water, or credited plan to go on shutdown cooling?
   c) Discuss the long-term SG injection strategy
      i. Discuss whether licensee requests NSRC water purification, other plan for using cleaner water in the SGs long-term, or credited plan for going on shutdown cooling

SE Section 3.2.3.1.2 (Plant instrumentation)

1. Discuss instrumentation used to control the event (NEI 12-06 instrumentation list, Ref. 3 or 4) (North Anna FIP Section 2.3.6)

   a) Discuss any deviations from NEI 12-06 list
   b) Confirm available / accessible throughout event
   c) Confirm availability of backup methods for taking readings locally {procedures}

SE Section 3.1 (Overall Mitigating Strategy)

1. Summarize the sequence of events including the validation times, and the calculation times (North Anna FIP Section 2.3.1, 2.3.2, 2.3.3, 2.17)

References

1. EPRI Technical Report, “Use of Modular Accident Analysis Program (MAAP) in Support of Post-Fukushima Applications”, June 2013 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML13190A201)

2. Letter from Jack Davis (NRC) to Joseph Pollock (NEI), Endorsement of MAAP4 Computer Code, October 2013 (ADAMS Accession No. ML13275A318)

3. NEI 12-06, Revision 2, December 2015 (ADAMS Accession No. ML16005A625)

4. NEI 12-06, Revision 0, August 2012 (ADAMS Accession No. ML12242A378)

5. PWROG-14027-P, Revision 3, April 2015 ADAMS Accession No. (ML15120A070)

6. Westinghouse TR-FSE-14-1-P, "Use of Westinghouse SHIELD Passive Shutdown Seal for FLEX Strategies," Revision 1, March 2014 (ADAMS Accession No. ML14084A497)

7. Flowserve White Paper on the Response of the N-Seal Reactor Coolant Pump Seal Package to ELAP, Revision A, August 2015 (ADAMS Accession No. ML15222A366)

8. Letter from Jack Davis (NRC) to James Gresham (Westinghouse), SHIELD Seal Endorsement Letter, May 2014 (ADAMS Accession No. ML14132A128)

9. Letter from Jack Davis (NRC) to Jack Stringfellow (PWROG), Endorsement of Flowserve N-Seal RCP Seal White Paper, November 2015 (ADAMS Accession No. ML15310A094)

10. PA-ASC-1187, Westinghouse Response to NRC Generic Request for Additional Information (RAI) on CENTS Code in Support of the Pressurized Water Reactor Owners Group (PWROG), November 2013 (ADAMS Accession No. ML14218A083)

11. Westinghouse Response to NRC Generic Request for Additional Information (RAI) on Boron Mixing in Support of the Pressurized Water Reactor Owners Group (PWROG), August 2013 (ADAMS Accession No. ML13235A135)

12. Letter from Jack Davis (NRC) to Jack Stringfellow (PWROG), Boron Mixing in Support of PWROG, January 2014 (ADAMS Accession No. ML13276A183)