Enclosure 2

NEI Response to NRC Request for Additional Information – Date October 30, 2008, RAI 7 and RAI 13

NEI 07-01, "*Methodology for the Development of Emergency Action Levels (for) Advanced Passive Light Water Reactors*"

Introduction

To better understand NEI's response to RAI 7 and 13, an explanation of plant response to loss of offsite power and proposed changes to NEI 07-01 cold shutdown EALs are presented for both the AP 1000 and ESBWR.

Plant Response to Loss of AC Evaluation for AP1000

In the event of a loss of Normal Residual Heat Removal System (RNS) during shutdown, coolant inventory could be boiled away. When the hot leg water level indicates that the loops are empty, IRWST injection and 4th-stage ADS are actuated following a delay after receipt of the empty hot leg level signal. This delay is integrated into the logic for two reasons:

- To allow the operators time to effect manual actions prior to ADS opening.
- To allow time to evacuate containment prior to ADS opening.

There are two safety-related RCS hot leg level channels, one in each hot leg. These channels provide the following protection functions:

- Isolation of letdown on low level on a one-out-of-two basis
- Actuation of 4th-stage ADS on Low-4 hot leg level on a two-out-of-two basis.
- Actuation of 4th-stage ADS also causes actuation of IRWST injection

These functions protect the plant, including during shutdown operations. In addition, the passive systems are available during shutdown modes to mitigate the consequences of an accident, which results in a significant improvement in shutdown risk.

During shutdown, the Core Makeup Tanks (CMTs) are available to provide RCS makeup in Modes 3, 4, and 5 until the RCS pressure boundary is open and the pressurizer water level is reduced. During Modes 3, 4 and 5 the primary signal that actuates the CMTs due to a loss of inventory is the pressurizer level signal. In Mode 5 with the RCS open, the CMTs are not required to be available and the RCS makeup function is provided by the IRWST. The CMTs also provide emergency boration function for accidents such as steam line breaks.

Whenever the CMTs are blocked during shutdown conditions, the ADS 1st, 2nd and 3rd stage valves are open to facilitate venting of the RCS, which precludes pressurization of the RCS. This alignment also allows the IRWST to automatically provide injection flow if it is actuated on a loss of decay heat removal. During reduced inventory operations, two of the four 4th-stage valves are required to be available.

In addition, the PRHR Hx. provides decay heat removal in shutdown Modes 3, 4, and 5 until the RCS is Open. In modes with the RCS Open, which includes portions of Mode 5 and Mode 6, decay heat removal is provided by the injection of water from the IRWST and venting or steaming through the ADS valves. This is a "feed and bleed" alignment.

The functional design requirements for the Passive Cooling system features ensure that the plant can be brought to a stable condition using the PRHR Hx for events not involving a loss of coolant. For these events, the Passive Cooling system, in conjunction with the passive containment cooling system (PCS) has the capability to establish long-term safe shutdown conditions, cooling the RCS to less than 420°F within 36 hours, with or without the RCPs operating.

During shutdown, the IRWST is available until Mode 6, when the reactor vessel upper internals are removed and the reactor cavity flooded. The IRWST injection paths are actuated on a low-2 CMT water level, which is available in Modes 3, 4, and 5 with the RCS intact, and does not require ac power to function. When the RCS is open to transition to reduced inventory operations, the CMT actuation logic on low pressurizer level is removed and the CMTs can be taken out of service. For these modes, automatic actuation of the IRWST can be initiated on a 2-out-of-2 basis on low hot leg level (Hot Leg Low-4), again without the need for ac power to be successful.

Loss of AC Power:

For LOCA and other postulated events where AC power sources are lost for greater than 22 hours, or when the CMT levels reach the ADS actuation setpoint, the ADS initiates. This also results in injection from the accumulators and subsequently from the IRWST, once the RCS is nearly depressurized. For these conditions, the RCS depressurizes to saturated conditions at about 240°F within 24 hours. The Passive Cooling Systems (PXS) can maintain this safe shutdown condition indefinitely as this is an alignment which facilitates recirculation with the containment closed.

A significant delay is provided between the accident/ADS stage opening and the initiation of recirculation – at least 2 hours – for the reasons delineated above. The recirculation screens have conservative flow areas to account for plugging. Adequate PXS performance can be supported by one screen with more than 90% of its surface area completely blocked.

<u>Operation during Loss of Normal Residual Heat Removal Cooling During Mid-Loop</u>:

The most limiting shutdown condition anticipated is with the reactor coolant level reduced to the hot leg (mid-loop) level and the RCS pressure boundary opened. This can occur during the normal practice to open the steam generator channel head manway covers to install the hot leg and cold leg nozzle dams during a refueling outage. In this situation, RNS is used to cool the RCS. Because the RNS is nonsafety-related, its failure has been considered in the AP1000 design.

In this situation, core cooling is provided by the safety-related PXS using gravity injection from the IRWST, while venting through the ADS valves, and possibly other openings in the RCS. With the RCS depressurized and the pressure boundary opened, the PRHR Hx is not used to remove decay heat because the RCS cannot heat sufficiently above the IRWST temperature. Prior to initiating the draindown of RCS to mid-loop level, the ADS 1^{st}, 2^{nd} and 3^{rd}-stage valves are opened. These ADS valves are required to be opened before blocking the CMTs.

The IRWST injection squib valves and 4^{th} stage ADS valves are automatically opened if the RCS hot leg level decreases below a low setpoint (Low-4). A time delay is provided to provide time for the operators to restore nonsafety-related decay heat removal prior to actuating the PXS and to evacuate containment. The time delay with an alarm in the containment also serves to protect maintenance personnel. Containment recirculation flow would be automatically initiated when the IRWST level drops to a low level to provide long-term core cooling.

Containment closure capability is required to be maintained during mid-loop operation. With the containment closed, containment recirculation can continue indefinitely with decay heat generating steam condensed on the containment vessel and drained back into the IRWST and/or directed to containment recirculation.

For a reduced inventory condition, if the time to steaming inside containment following a loss of heat sink event is less than the time required to close the containment equipment hatches, then these hatches should be closed. The RCS Hot Leg level instruments are required be operable and available prior to reduced inventory operations.

Loss of RNS Cooling In Mode 4 with RCS Intact:

It is assumed a loss of offsite power occurs, resulting in a loss of RNS cooling. Because the Mode 4 plant conditions assumed for the analysis are more limiting than Mode 5 conditions, this analysis is also applicable for a loss of RNS cooling in Mode 5 when the RCS is intact. Therefore the Mode 4 analysis "bounds" the Mode 5 analysis.

It is assumed that CMTs are available for injection. Two cases were analyzed, one crediting operator action. We will consider the first, which only credits automatic safety system actuation on a low pressurizer level late in the event. Therefore, the only mechanism for removing decay heat is boiling off the RCS inventory and venting through the RNS relief valve.

Automatic Safety Injection Case (Limiting):

The RCS heatup causes system pressure to increase until the pressure reaches the RNS relief valve setpoint of 500 psig in a little over 6 minutes. The normal relieving capacity of the valve is 850 gpm. The RCS temperature increases until the core outlet temperature reaches saturation at the relief valve setpoint at ~ 53.33 minutes.

A mixture level begins to form in the upper plenum at ~63.5 minutes and drops to the top of the hot-leg elevation. Eventually, enough mass will be discharged such that a mixture level forms in the downcomer region and the downcomer level begins to decrease. As the boiling moves lower and lower, more steam generation occurs and pressure increases. When the length of the core is boiling, which is acceptable, the mixture level is still within the hot leg perimeter. Pressurizer level begins to decrease as water drains from the pressurizer into the RCS hot leg. The CMTs actuate and reach the fourth-stage ADS setpoint of 20 % level. Two of the four fourth-stage paths open at ~ 2.84 hrs.

As noted previously, it is assumed that one of the fourth-stage paths is out of service and one path is assumed to fail as the single active failure. The vapor and flow through the fourth-stage ADS paths further reduces the pressure to the point where the IRWST injection begins at approximately 2.9 hours, ac power is not required. The analysis results show that the RCS mass inventory twice reaches a minimum of approximately 110,000 pounds when the CMT and IRWST injection increase the inventory. This mass is in excess of the amount necessary to ensure that the reactor core remains covered. The RCS mass inventory is greater than 200,000 pounds and is slowly increasing at the end of the transient. The analysis concludes that the consequences of a loss of RNS in Modes

4 and 5 with the RCS intact are acceptable with a single failure and without core damage or core uncovery.

Loss of RNS Cooling in Mode 5 with the RCS Open:

For this analysis, it is assumed that the RNS is in operation in Mode 5 at 24 hours after reactor shutdown with the ADS Stage 1, 2 and 3 valves open and the RCS vented to the IRWST. The reactor coolant temperature is assumed to be at 160°F, and the pressurizer is assumed to be at atmospheric pressure plus the elevation head in the IRWST, or 18.2 psia. In addition, one of the two available fourth-stage ADS valves is assumed to fail to open on demand as the single failure. It is assumed that a loss of offsite power occurs, resulting in a loss RNS cooling. Following the loss of RNS cooling, there is no active mechanism for heat removal from the RCS and the core decay heat generation results in an increase in the reactor coolant temperature. The RCS temperature increases until about 50 minutes when saturation is reached. The venting of the RCS through ADS allows pressure to remain constant for a little longer. Eventually, a vapor/water mixture is being vented through the ADS valves and pressure rises to about 44 psia and then drops again.

The hot leg is empty at approximately 80 minutes. This is the normal signal for opening fourth-stage ADS valve and to initiate IRWST injection when the systems are aligned for automatic actuation. Downcomer pressure is reduced to the point where IRWST injection, which does not require ac power, is initiated at approximately 92 minutes. The IRWST injection quickly reverses the decrease in the core stack and downcomer mixture levels. The core stack mixture level is maintained well above the elevation of the top of the core active fuel throughout the transient. RCS inventory reaches a minimum of approximately 135,000 lbm and then begins to increase as a result of the IRWST injection. Thus it is concluded that one ADS Stage 4 valve is effective in reducing system pressure so that the consequences of a loss of RNS in Mode 5 with the RCS vented are acceptable.

During Mode 5, prior to draining to mid-loop conditions, the operator manually opens the ADS Stages 1 through 3 paths to the IRWST. With the RCS "open" the operator then proceeds to slowly drain the RCS to mid-loop conditions for performing maintenance. In general, the results of a loss of RNS during mid-loop conditions are similar, but slightly less severe to those presented in this evaluation due to the lower levels of decay heat and the absence of the initial water inventory in the pressurizer. This serves to reduce the surge line flooding phenomenon that degrades the depressurization capability of the ADS Stages 1 through 3 vent paths. Acceptable results considering a single failure and without core damage or core uncovery are rendered for these analyses.

<u>Plant Response to Loss of AC Evaluation for ESBWR</u>

Excerpts from ESBWR DCD Section 15.5.5 and Table 15.5-10a for Station Blackout

This assumes 1) no transfer to "Island mode" and 2) standby diesels do not start

The analysis assumptions and inputs are summarized below.

- Reactor is operating initially at 102% of rated power/100% rated nominal core flow, nominal dome pressure and normal water level at L4. The reactor has been operating at 102% of rated power for at least 100 days.

- SBO starts with loss of all alternating current (AC) power, which occurs at time zero. Auto bus transfer is assumed to fail. Failure to transfer to "Island mode."
- Loss of AC power trips reactor, feedwater, condensate and circulating water pumps, and initiates a turbine load rejection.
- The reactor scram occurs at 2.0 seconds due to loss of power supply to feedwater pumps. When feedwater flow is lost, there is a scram signal with a delay time of 2.0 seconds.
- Bypass valves open on load rejection signal.
- Closure of all Main Steam Isolation Valves (MSIVs) is automatically initiated when the reactor water level reaches Level 2 after 30 second time delay. The valves are fully closed at 5.0 seconds after signal.
- CRD pumps are not available due to loss of all AC power. The systems available for initial vessel inventory and pressure control, containment pressure/temperature control and suppression pool temperature control are:
    - Three Isolation Condensers; and
    - The rest of the safety systems are not credited or they do not actuate during the calculated sequence of events.
- The passive ICS is automatically initiated upon the loss of feedwater pump power buses at 3 seconds to remove decay heat following scram and isolation. Isolation condenser drain flow provides initial reactor coolant inventory makeup to the reactor pressure vessel.
- The vessel depressurizes, the vessel and other components inventory remains constant; however, the measured level changes because reactor pressure and liquid temperature changes.

Analysis Results

During the first 20,000 seconds of depressurization, level is maintained above Level 1. Vessel inventory analysis demonstrates that level remains above Level 1 during the first 72 hours of the transient. Therefore, the requirement for reactor vessel coolant integrity is satisfied. The wide range measured level is above 13.5m (44.3 ft) above vessel zero, which provides adequate margin to L1 ADS analytical limit [11.5m (37.7 ft) above vessel zero]. The collapsed water level remains well above TAF.

Subsequent to a SBO event, hot shutdown condition can be achieved and maintained by operation of ICS. Therefore, the requirement for achieving and maintaining hot shutdown condition is met.

With operation of the ICS, the containment and suppression pool pressures and temperatures are maintained within their design limits since there is no release into the wetwell or the drywell. Therefore, the integrity for containment is maintained.

RPV leakage is expected to be minimal for three reasons: 1) there are no recirculation pumps in the design; 2) isolation occurs on L2; 3) the pressure is reduced significantly by the ICS. However, if leakage is significant and power has not been restored, the level could drop below the L1 setpoint. In this case ADS, GDCS and PCCS are available to provide core cooling, inventory control and containment heat removal. Because significant depressurization is provided by ICS, the impact of depressurization due to ADS initiation would not be as significant as initiation from rated pressure.

As demonstrated above, each acceptance criterion in Subsection 15.5.5.1 is met. Therefore, ESBWR can successfully mitigate a SBO event to meet the requirements of 10 CFR 50.63.

This event bounds AOOs with respect to maintaining water level above the top of active fuel. Reanalysis of this event is performed for each fuel cycle.

Excerpt from ESBWR TS Bases B3.5.5

The ICS is designed to operate either automatically or manually following reactor pressure vessel (RPV) isolation to provide adequate RPV pressure reduction to preclude safety/relief valve operation and provide core cooling while conserving reactor water inventory (Ref. 1). When the reactor is shutdown, a reduced ICS capability is maintained to provide cooldown capability and to ensure a highly reliable and passive alternative to the Reactor Water Cleanup/Shutdown Cooling System (RWCU/SDC) system for decay heat removal.

RWCU/SDC consists to two independent and redundant trains powered from separate electrical divisions that can be powered from either offsite power or either of the station diesel generators. However, RWCU/SDC is a nonsafety-related system that cannot be assumed to remain available following an equipment failure or a loss of offsite power. Depending on plant and equipment status, various alternatives to the RWCU/SDC for decay heat removal can be configured in MODES 3, 4 and 5. When the IC/PCC pool and the individual ICS pool subcompartments are flooded, use of one or more ICS loops is the preferred backup method for decay heat removal in MODES 3 and 4.

Although not effective for decay heat removal in MODE 5, the ICS does provide a highly reliable and passive backup to the RWCU/SDC for decay heat removal in this MODE. If normal decay heat removal capability is lost, the reactor coolant temperature will increase until the ICS provides the required decay heat removal capacity.

Proposed Changes to EALs

CA3 "Loss of all off-site and all on-site AC power for 60 minutes or longer" was added to NEI 07-01. This EAL recognizes that a loss of AC electrical may result in activation of the passive decay heat removal system. Time frames selected to restore AC power were selected based on analysis that indicate no challenges to the passive cooling systems before these times.

RAI #7, Station Blackout EALs

1. Please explain in much greater detail why the NRC should consider the removal of EALs related to loss of AC power during cold shutdown and/or refuel op modes given there is no temperature differential to allow for "boil off' or natural circulation.

   NEI Response:

   NEI reevaluated the need for cold shutdown EALs.

   CA3 Loss of all off-site and all on-site AC power for 60 minutes with RCS open and 120 minutes with RCS intact was added. The 60 and 120 minute time frames were chosen based on analysis that indicates that prior to this time frame the passive cooling system is not challenged and therefore the times are warranted to allow for recovery of the AC power prior to escalation to the Alert.

2. In light of SECY-95-132 and section 8.5.2.3 of the AP1000 SER, provide further explanation regarding the removal of SBO EALs for all applicable operating modes.

   NEI Response:

Active systems that normally provide core cooling in all modes for AP 1000 and ESBWR are not safety related.

However SECY-95-132 states that these systems do provide defense in depth capabilities for reactor coolant makeup and decay heat removal[1]. These systems are the first line of defense to reduce challenges to the passive systems. Therefore, an AC electrical EAL CA3 was developed.

RAI #13 CU3 and SU1

The loss of power to the battery chargers for the class 1E DC distribution system identified as the proposed IC could be caused by a loss of offsite power and by a loss of the standby diesel generator. As such, the proposed IC obscures the fundamental concern of NEI 99-01 IC CU3, namely the loss of offsite power. The proposed basis advances the argument that since the ALWRs do not have safety grade diesels but rely instead upon the safety related batteries, the loss of offsite AC power doesn't warrant a NOUE classification. The staff disagrees in that [Each of NRC's sub-questions 1 to 7 appear below NEI's introductory paragraph.] :

NEI Response:

The fundamental concern of NEI 99-01 IC CU3, namely the loss of offsite power, is not a basis for requiring the same EAL in NEI 07-01. NEI provides the following additional justification for each of the NRC's support discussions to correct NRC's ALWR design misconceptions.

1. A declaration under NEI 99-01 IC CU3 is not a function of the emergency diesel generators nor the DC batteries.

   NEI Response:

   Agreed. A declaration under NEI 99-01 IC CU3 is not a function of the emergency diesel generators, but a function of being one failure away from a loss of forced RCS cooling. Unlike the conventional plant the AP1000 and ESBWR have additional passive systems that keep the core cool after a loss of AC electrical and forced cooling.

   Declaration under NEI 99-01 IC CU3 is not a function of DC batteries. However NEI 07-01 CU3 is intended to be a function of DC batteries. NEI 07-01 CU3 is provided as a precursor to NEI 07-01 CA4. The precursor EAL CU3, requires an NUE declaration when all safety related DC batteries are not being charged for 30 minutes or longer. Since passive systems require one-time alignment of safety related valves that have DC motor operators which rely on safety related DC batteries loss of DC power potentially compromises passive safety related plant systems requiring electric power and is therefore an appropriate precursor to NEI 07-01 CA4.

[1] SECY-95-132, Attachment 2, Section A, Paragraph 3.

2. Offsite AC power, the fundamental subject of IC CU3 is not safety-related at any current or proposed reactor. Thus, the non-safety configuration of the ALWR AC distribution is not justification for this ALWR specific deviation from NEI 99-01.

   NEI Response:

   Agreed. The non-safety configuration of the ALWR AC distribution is not justification for this ALWR specific deviation from NEI 99-01.

   NEI 99-01 CU3 Basis states that the additional single AC failure would result in Station Blackout. Station Blackout results in a loss of cooling to the core in a conventional plant. An additional single failure of the AC electrical system in a passive plant does not result in a loss of cooling to the core. As long as the DC electrical system is operational, passive cooling capability remains.

3. As stated in the NEI 99-01 bases, unplanned loss of offsite AC power reduces required redundancy and potentially degrades the level of safety of the plant by rendering the plant more vulnerable to a complete loss of AC power (e.g., station blackout). In addition, the loss of offsite AC power forces the licensee to rely solely on equipment powered through the emergency buses to control and shutdown the plant, thereby complicating the shutdown. The fact that the ALWR emergency buses are DC rather than AC does not change the need for the licensee to rely on equipment powered through the emergency buses only nor does it eliminate complicating the shutdown, degradation in the level of safety of the plant.

   NEI Response:

   The ALWR design is not vulnerable to a complete loss of AC power (e.g. Station Blackout) therefore the NEI 99-01 Basis does not apply to NEI 07-01. In the ALWR design there are no AC emergency busses. The plant is designed to automatically establish and maintain safe shutdown conditions without operator actions during Station Blackout[2].

4. The operability of the Class 1E DC power subsystems (and by extension power sources needed to make the chargers operable) is addressed under Technical Specification 3.8.1, and the outage of the chargers would be addressed under IC SU2.

   NEI Response:

   Agreed that operability of the DC power subsystem is addressed under Technical Specification 3.8.1, and the outage of the chargers under IC SU2, however EAL usage dictates that the Emergency Coordinator evaluates ICs starting from General Emergency to NUE. SU1 is part of the SG1, SS1, SA1 and SU1 and should be retained to avoid misclassification of an NOUE for this condition.

5. The argument regarding Technical Specification 3.9 is non-persuasive in that the existing LWR fleet has a corresponding limitation. The staff also notes that this LCO is driven largely by the offsite dose consequences of a fuel handling accident rather than by decay heat.

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[2] Reference WCAP-15985, page 5-1, section 5.1, paragraph 3 and ESBWR DCD Section 15.5.5.

NEI Response:

The applicable EALs have now been included in NEI 07-01, and the basis for them now addresses the applicable and appropriate operations and design considerations.

Although TS 3.9 is based on fission product inventory in the damaged fuel rods, by assuming at least 24 hours of decay time the reference to TS 3.9 establishes a maximum decay heat load from which heat up calculations for a refueling configuration begin.

6. The battery chargers are powered from 480 VAC buses that are normally powered by offsite power or the main generator, but can be powered by the non-Class 1E standby diesel generators, which are onsite power sources, even if they are non-Class 1E. By focusing on the existence of power on this bus, the CU3 focus on the availability of offsite power is inappropriately diminished.

NEI Response:

NEI believes that it is appropriate to diminish the focus on the availability of off-site power in the ALWR design and refocus the IC on the safety related battery systems. The ALWR design is not vulnerable to a complete loss of AC power, therefore the NEI 99-01 CU3, a precursor EAL to CA3, which requires declaration of a NOUE in a single AC source situation is not warranted in NEI 07-01.

7. The progression of events identified in the bases, namely, boiling in the IRWST and activation of passive IRWST injection would be a significant transient on the plant the response to which warrants an emergency classification greater than NOUE. (Cold/Refuel)

NEI Response:

Agree. Boiling in the IRWST would be a significant transient on the plant the response to which warrants an emergency classification greater that NOUE. If this condition occurred an Alert would be declared based on allowable grace periods provided in the RCS Reheat duration table. No modification to NEI 07-01 is required to address the above concern.

Please modify the proposed EAL and its basis accordingly or provide additional justification for this deviation.

NEI Response:

Justification for deviation from CU3 are discussed above. A modified CA3 was provided for NEI 07-01.