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MFN 07-214

Docket No. 52-010

May 16, 2007

U.S. Nuclear Regulatory Commission
Document Control Desk
Washington, D.C. 20555-0001

Subject: Response to Portion of NRC Request for Additional Information Letter No. 88 Related to ESBWR Design Certification Application ESBWR Probabilistic Risk Assessment RAI Numbers 19.1-43 through 19.1-62,19.1-64 and 19.1-65.

Enclosure 1 contains GE's response to the subject NRC RAIs transmitted via the Reference 1 letter.

If you have any questions about the information provided here, please contact me.

Sincerely,

Kathy Sedney for

James C. Kinsey
Project Manager, ESBWR Licensing

D068

Reference:

MFN 06-385, Letter from U.S. Nuclear Regulatory Commission to David Hinds, Request for Additional Information Letter No. 73 Related To ESBWR Design Certification Application, October 8, 2006.

Enclosures:

1. Response to Portion of NRC Request for Additional Information Letter No. 88 Related to ESBWR Design Certification Application ESBWR Probabilistic Risk Assessment RAI Numbers 19.1-43 through 19.1-62,19.1-64 and 19.1-65.

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EDRF Section 0067-5912

Enclosure 1
MFN 07-214
Response to Portion of NRC Request for Additional Information Letter No. 73 Related to ESBWR Design Certification Application ESBWR Probabilistic Risk Assessment RAI Numbers 19.1-43 through 19.1-62,19.1-64 and 19.1-65

NRC RAI 19.1-43

Provide cutsets for each fault tree diagram reported in Chapter 4 Appendices. --- Please provide tables of cutsets for each of the fault tree diagrams reported in Chapter 4 of the PRA. Include up to four term cutsets or top 100, whichever is less. This information will be very useful to the staff's efficient review of the PRA.

GE Response

NEDO-33201 Rev 2 Chapter 4 provides the response to this RAI.

Cutset tables have been added for each individual system.

Affected Documents

No DCD changes will be made in response to this RAI.

NEDO-33201 Chapter Rev 2 has been revised as noted above.

NRC RAI 19.1-44

Modeling of Intersystem Common Cause Failures -- No intersystem Common Cause Failures (CCFs) appear to be modeled in the PRA. Please discuss the potential for such CCFs and what ESBWR design features are in place that prevent or minimize inter-system CCFs.

GE Response

Intersystem Common Cause Failures (CCF) have more barriers and defenses than those usually available within a system. Although CCFs can not be excluded, the likelihood of intersystem CCFs is significantly reduced by a number of ESBWR design features, such as the:

- High degree of physical separation of the systems involved in the PRA models.
- High degree of diversity between safety related and defense-in-depth systems.
- Significant differences in the design, process and environmental conditions and physical location.

Based on the above considerations, intersystem CCFs are not explicitly modeled, except that intersystem dependencies are modeled via transfer gates for supporting systems within each system and common cause failures are modeled where relevant in the supporting systems. Section 5.3 of NEDO-33201 also addresses intersystem dependencies. Individual system notebooks will discuss supporting systems and transfer gates where relevant. The notebooks are available for NRC Staff review at the GE Wilmington, North Carolina offices.

Affected Documents

No DCD changes or NEDO-33201 changes will be made in response to this RAI.

NRC RAI 19.1-45

Simplified block diagrams for the signal generating portion of I&C,including element descriptions and important assumptions. -- For each system modeled in the PRA, please provide simplified block diagrams for the signal generating portion of I&C (which is not discussed in Section 4.5 of the ESBWR PRA) supporting the fault trees provided in the Sections of Appendix B. Please include a description of each element (including basic events) and important assumptions made in the PRA model. -2-

GE Response

The I&C system is being implemented in the ESBWR certification using Design Acceptance Criteria. As such, the detailed design is not available. The DCD PRA models this system in a bounding manner that captures the important features and dependences of the systems likely to be implemented in the final design. NEDO-33201 Revision 2 Section 4.5 contains a block diagram and assumptions used to develop the signal processing logic in the DCD PRA model.

Affected Documents

No DCD changes will be made in response to this RAI.

NEDO-33201 Rev 2 Section 4.5 has been revised as described above.

NRC RAI 19.1-46

Clarify how certain potential failures of the Automatic Depressurization System were modeled in the PRA.

Additional information in the following areas (Section 4.1 of the PRA) is required to determine whether certain potential failures of the automatic and manual control of the Automatic Depressurization System (ADS) were identified and modeled in the PRA:

(A) Please explain whether and how hardware failures associated with SRV solenoid operated valves and the configuration of load drivers are modeled in the PRA (for both automatic and manual actuation).

(B) Please explain whether and how hardware failures associated with DPV firing circuits (two initiators and one booster), load drivers, and the two timers (i.e., the main ADS timer and the high drywell pressure bypass timer) are modeled in the PRA (for both automatic and manual actuation).

(C) Please explain the purpose, the function and the operation of the main ADS and high drywell pressure bypass timers, including a discussion on how these timers impact plant response, with reference to accident sequences modeled in the PRA. Were beyond design basis conditions, such as those encountered in PRA accident sequences, considered in the design of these timers?

(D) It is stated that each ADS SRV line to the suppression pool "incorporates redundant vacuum breakers....[which] prevent waterhammer and pressure instability conditions in the SRV discharge line." Please explain how the failure of these vacuum breakers was treated in the PRA?

(E) ADS SRVs and DPVs must open following a small LOCA inside containment to allow operation of the low pressure core cooling systems. Since these valves are located inside the containment, they will have to open in a harsh environment. Studies and operational experience suggest that there is a potential for failure of power and control cables operating in harsh environments, which was not addressed in the ESBWR PRA. Please discuss.

(F) Please explain the assumptions and associated bases made in estimating the common cause failure (CCF) factors for the ADS DPVs. The staff notes that there is no actual operational experience with the type and size of squib valves used in the ESBWR design. The estimated CCF factor for a set of four or more squib valves by the approach recommended in ALWR Utility Requirements Document (ESBWR PRA Reference 5-1) is 4.2E-2, which is significantly higher than the 5E-3 value used in the ESBWR PRA. Please discuss. The staff believes that there is significant uncertainty associated with the CCF probability of DPVs and the impact of this uncertainty on the results and insights of the PRA should be investigated by sensitivity studies.

GE Response

A) Refer to NEDO-33201 Section 4.1.3.1. The hardware failures considered for the solenoid-operated SRVs include "fail to open in actuation mode". Only manual actuation is modeled. The data for this failure mode include solenoid-related failures. Load driver configuration is considered in the Q-DCIS and DPS system models.

B) Refer to NEDO-33201 Section 4.1.3.1. Hardware failures associated with the DPVs (including the four initiators and one booster) are captured in the data for "explosive valve fails to operate". Load driver configuration is considered in the Q-DCIS and DPS system models. The main ADS timer and high DW pressure bypass timer are both software routines, not actual hardware components. The "CCF of software" failure mode captures failures of the timer functions.

C) Refer to NEDO-33201 Section 4.1.4.1. The DCD explains the purpose and function of the timers in section 7.3.1.1.

D) Refer to NEDO-33201 Section 4.1.2 – assumption #3. The PRA only exposes the ADS SRVs to one actuation, so the valves and their discharge lines are not exposed to post-actuation condensation in the discharge line.

E) Addressed in NEDO-33201 Section 4.1.3.3. The DCD states that the mentioned components and all support equipment are designed for harsh DW conditions in NEDO-33201 Section 6.3.2.8.1.

F) As stated in NEDO-33201 Section 4.1.8, the general CCF methodology outlined in NEDO section 5.3 was followed for the ADS DPVs. As such, the generic MGL factors were used (b = 0.1, g = 0.5, and d = 0.9).

<u>Affected Documents</u>

No DCD changes will be made in response to this RAI.

NEDO-33201 Rev 2 has been revised as noted above.

NRC RAI 19.1-47

Clarify how certain aspects of the Isolation Condenser System were modeled in the PRA.

The staff needs additional information related to Section 4.2 Isolation Condenser System (ICS) in the following areas:

(A) One of the functions, of the ICS stated in Section 4.2 (page 4.2-1, second paragraph) of the PRA, is "to provide the means for initial depressurization of the reactor before ADS initiation from a low reactor water level." Please explain whether and how was the success or failure of this function modeled in the PRA.

(B) Clarify the description of the ICS initiation signals that are related to MSIV closure ,documented in Section 4.2.4, and their modeling in the PRA: (1) Define the terms "position switch" and 'limit switch" and their relationship to the operation of MSIVs, (2) Define failures and failure modes associated with the initiation signal(s), (3) clarify the success criteria for generating an ICS initiation signal, (4) Explain why no CCFs were considered for the groups of nitrogen and air operated MSIVs (operate to de-energized position), (5) Explain the basis of the MSIV failure data used (for the applicable failure mode), (6) Explain whether and how the manual initiation of ICS was modeled.

(C) It is stated that "the isolation condenser and drain piping are filled with condensate, that is maintained at a subcooled temperature by the pool water during normal water operation." Has the potential failure to maintain the condensate subcooled, and its impact on the ICS capability, been investigated? What features prevent the formation of a two-phase (water-vapor) mixture or single-phase (vapor) that could degrade the performance of the ICS? Please discuss.

(D) It appears that not all CCF combinations of the nitrogen-operated condensate return bypass valves (ICS-F006A,B,C,D) have been modeled in the PRA. Table 4.2-5 lists only one CCF event for these valves (event B32-ACV-CF-2IABCD). Please clarify.

(E) No common cause failure (CCF) to remain open was considered among the steam line motor-operated isolation valves F001A,B,C,D and F002A,B,C,D and the condensate line motor-operated isolation valves F003A,B,C,D and F004A,B,C,D. Please clarify.

(F) It appears that no failures of the vent lines (to the suppression pool) and the purge lines (to the main steam lines) were modeled in the PRA. Please clarify. Also, no discussion is provided for the potential failure or degradation of the ICS due to hydrogen buildup and air entrainment that could blanket with non-condensables the ICS condensate lines. Was this potential failure and its impact on the ICS capability investigated? What features prevent non-condensables from getting entrained into the ICS condensate lines? Please discuss.

(G) Please explain the assumptions and associated bases for estimating the CCF factors for ICS air-operated valves (AOVs) and motor-operated valves (MOVs). The staff notes that only five operating BWRs have isolation condensers and there are significant differences with the ESBWR ICS design. The estimated CCF factors for both MOVs and AOVs appear to be significantly lower than estimates obtained by the approach recommended in ALWR Utility Requirements Document. Please discuss. The staff believes that there is significant uncertainty associated with

the CCF probability of AOVs and MOVs and the impact of this uncertainty on the results and insights of the PRA should be investigated by sensitivity studies.

GE Response

NEDO-33201 Rev 2 Section (4.3) provides additional details and basis for response to this RAI.

(A) There is a tank in the condensate return line of the ICS. Upon actuation, the contents of this tank will be injected, causing an initial temperature and pressure drop. There are no specific control systems that perform this function. It is simply a result of injection. Therefore, no particular effects were modeled.

(B) (1) Limit switches are used on the MSIVs to detect the valve position. (2) The signals and their failure modes are completely developed in the C63 - QDCIS model. (3) ICS initiation logic is defined and built in the C63 model. (4) CCF is not modeled because the valves fail closed. CCF is only modeled for active components transitioning to an active state. (5) MSIV position is one of many signals that lead to ICS actuation. Even if they aren't credited, the impact would be negligible. (6) Manual initiation is modeled. It consists of a human action, and the failure of the QDCIS hardware that is required for manual actuation.

(C) There are no mechanisms by which the water in the condensate return pipes could be heated above ambient. There are two isolation valves at one end, and a loop seal at the other. The fluid is not in motion.

(D) Common cause has been completely redone for ICS. Details for these events (including the methodology, MGL factors, and component groupings) are in NEDO 33201 Rev 2 Section 5.3. ICS events are listed in Table 4.3-4.

(E) Spurious closure is a rare event. As such, CCF combinations are even rarer. There are other failures that would disable the ICS far more frequently. Those failures overwhelm the rare event of spurious closure.

(F) The lower head vent paths are now modeled. Per the PANTHERs report, the upper head vent paths do not provide any significant gas removal. The requirement for venting is modeled as a conditional event, currently set to a probability of 1.0.

(G) The CCF factors used in the ICS model are the generic CCF values. They are not adjusted due to the unique application of the hardware.

Affected Documents

No DCD changes will be made in response to this RAI.

NEDO-33201 Rev 2 has been revised as described above.

NRC RAI 19.1-48

Justify and/or clarify assumptions or potential missing information in modeling the Control Rod Drive System in the PRA.

The staff needs additional information related to Section 4.3 Control Rod Drive System (CRDS) in the following areas:

(A) Suction manual valves F013A&B, F015A&B, F003A&B and injection manual valves F021A&B are assumed normally open. The only failure modeled is single "manual valve mis-positioning" following maintenance. Please explain why no common cause failure (CCF) of combinations of two or more manual valves, due to mis-positioning,was considered. Also, explain why CCF of orifices D007A&B (plug) was not considered.

(B) Fault trees and Table 4.3-7 (System Basic Events) refer to manual valves F018A&B which are not mentioned in the text or shown in the CRDS flow diagram. Instead,manual valves F003A&B are shown in the flow diagram. Are they the same? Please clarify.

(C) A CCF to open basic event (C12-MOV-CF-OPEN) for motor operated valves (MOVs) was considered. Since there are two pairs of MOVs (F014A&B and F020A&B) that can fail to open due to common cause, the definition of event C12-MOV-CF-OPEN is not clear. Please clarify.

(D) The flow diagram and text (page 4.3-3) refer to one valve F023 and one valve F024 while Table 4.3-2 lists valves F023A&B and valves F024A&B. Please clarify.

(E) It is stated (page 4.3-2) that "Upon receipt of a reactor water level 2 signal, the CRD shifts to the water injection mode of operation. The standby pump starts, the purge water header valve F012 and the charging water header valve F030 close ....."However, the failure (both single and common cause) of valves F012 and F030 to close is not modeled. Please explain.

(F) The flow diagram shows valves F01T and CV01T on the line from the Condensate and Feedwater. However, these valves are modeled in the fault trees as being on the line from the Condensate Storage Tank (CST). Please clarify. Also, provide the basis for the assumption that the source of water from the Condensate and Feedwater is adequate for the mission time and for all sequences where the CRDS is credited.

(G) Please provide the basis for the assumed unavailability of one train of the CRDS due to maintenance (3E-3). What are the technical specifications for this system?

(H) It is stated (page 4.3-2) that "...no room cooling for the CRDS compartment is required for the first 24 hours of the accident." Are there any accident sequences for which the CRDS is needed, as modeled in the PRA, for longer times (i.e., beyond 24 hours)?Please explain.

(I) It is stated that "Initiation of the CRDS automatically generates the automatic opening and closing of valves F023 and F024, respectively." Please clarify whether valve F024 is normally closed (as shown in the flow diagram) or open as the above statement implies. If it is normally open, then, its failure to close has to be modeled in the PRA.

GE Response

(A)CCF was not considered for mis-positioning of manual valves at this time because there is sufficient conservatism in the screen value used for each event itself. Should the events appear in cutest(s) indicating the need for additional analysis HRA values will be applied and CCF will be considered at that time.

Due to the purity of the water in this system it is highly unlikely that a system based failure mechanism exists which would result in plugging either orifice. The inclusion of the potential plugging of D007A&B was to address the low probability occurrence of foreign material entry into the system. It was not considered credible that there would be sufficient foreign material to plug both trains given that one was in operation at all times; therefore, without a credible common cause failure mechanism, no common cause failure was considered.

No changes to the DCD or NEDO-33201 will be made in response to Part A of this RAI.

(B) NEDO-33201 Rev 2 Table 4.3-7 provides the response to this RAI.

F018A&B and F003A&B are not the same, the current drawings do not indicate F018A&B exist; all reference to them has been removed from the fault tree and Table 4.3-7.

(C) F014A&B are 200mm valves while F020A&B are 125mm valves, a significant difference; at this time the specific manufacturer of the valves has not been decided. Given the significant size difference and the unknown manufacturer it cannot be determined at this point if a common cause failure mechanism exists between the two sets of valves; therefore, the model currently does not contain this basic event. No changes to NEDO-33201 will be made in response to Part C of this RAI.

(D) NEDO-33201 Rev 2 Table 4.3-2a provides the response to this RAI.

Table 4.3-2a has been corrected, there is only one F023 and one F024.

(E) Should either F012 or F030, or both, fail to close the maximum flow diverted from CRDS injection is ~20.5% of total CRDS flow; however, this flow is still injected into the RPV. No changes to NEDO-33201 will be made in response to Part E of this RAI.

(F) NEDO-33201 Rev 2 Section 4.3-3.1 provides the response to this RAI.

Valves F01T and CV01T have been renumbered to F064 and F063 respectively; these valves are on the Condensate and Feedwater line into the CRDS and the model has been changed appropriately. Additionally, the CST can feed the CRDS through locked-open valve F065, which is modeled as well. Whichever source has the highest pressure will provide the input to CRDS.

(G) There are no technical specifications related to the injection function of the CRDS. No changes to NEDO-33201 will be made in response to Part G of this RAI.

(H) NEDO-33201 Rev 2 Section 4.3-3.3 provides the response to this RAI. For the current revision there are no accident sequences for which CRDS is credited beyond 24 hours. Additionally, there is no reference indicating room cooling is necessary; the motor oil is cooled with RCCW (which is modeled). This statement has been deleted.

(I) NEDO-33201 Rev 2 Section 4.3-4.1 provides the response to this RAI. F024 is normally closed as indicated in the flow diagram. Its sole function is to support flow testing; only during testing would F023 be closed and F024 be open.

Affected Documents

No DCD changes will be made in response to this RAI. NEDO-33201 Rev 2 Section 4.3-1 has been revised in response to this RAI.

NRC RAI 19.1-49

Clarify/explain how certain aspects of the Standby Liquid Control System were modeled in the PRA.

The staff needs additional information related to Section 4.4 Standby Liquid Control System (SLCS) in the following areas:

(A) It is stated (page 4.4-1) that "no maintenance is expected to occur during power operation that makes either train of the SLCS unavailable." This statement implies that no preventive maintenance and no system outage for testing is expected. However,corrective maintenance may be needed that could impact the availability of one train during operation at power. As stated on page 4.4-4, "...the SLCS can be maintained while the plant is in normal operation, subject to technical specification requirements and limitations." Please explain why no unavailability due to test and maintenance was considered.

(B) It is stated (page 4.4-9) that "The SLC system and components shall be designed such that they can be maintained with relative ease and minimum maintenance time." This statement implies that the SLCS is not yet designed. Please clarify. Does this statement refer to both preventive and corrective maintenance? Please list the features that the system has to possess to ensure minimum maintenance time.

(C) It appears that the system has four manual valves which are locked open during operation at power (F001A&B and F006A&B). It is stated (page 4.4-4) that "Mispositioning of valves F001A, F001B, F006A and F006B is not considered an error because they are checked periodically. All normally-open manual isolation valves are subject to being left in the closed position following maintenance. The probability of this is included in the analysis." It appears that the second sentence negates the first sentence. Regarding the third sentence, the staff could not find documentation on how the subject failure was included in the analysis. Please clarify and state how and how often these valves are checked.

(D) Table 4.4-3 indicates that manual valves F006A&B are tested quarterly while manual valves F001A&B are tested during plant outages. Please state the reason for the different testing intervals and explain whether and how these intervals were modeled in the PRA.

(E) It is stated (page 4.4-3) that "Following firing of the squib valves....When each tank reaches a set low value, local instrumentation closes the respective motor-operated valves F002A and B to prevent the injection of nitrogen into the RPV. The same signal ....opens the diverse accumulator depressurization valves F507A and B and F508A and B after a delay." Is the failure of these valves to change status modeled in the PRA? Please explain.

(F) The failure of long-term boration during ATWS (top event GC-0001__1) is modeled in the fault tree (page 1 of App. B.4.4) with an AND gate and requires the failure to inject boron by both SLCS loops and the failure of boration through the "working inventory make-up systems." The means of providing boration through the "working inventory make-up systems" is not discussed in Section 4.4. Please discuss how boron make-up is provided and how its failure is modeled (e.g., events C41-XHE-FO-INISL-CS and C41-SYS-FF-MAKEUP and associated failure probabilities).

(G) It appears that no common cause failures (CCFs) between similar components of the two SLCS loops were considered. Please explain.

(H) Check isolation valves F004A&B and F005A&B are tested during plant outages. Their failure to open probability is assumed to be 1.6E-3. Please discuss under what conditions these valve operate (e.g., differential pressures during normal plant operation) and explain how their failure probability was calculated.

(I) Please explain how the CCF probability of squib valves (1.5E-4) was calculated. Also,please discuss how and how often the squib valve actuators are tested.

(J) It is stated (page 4.4-4) that "The system fault tree analysis is based on a test interval of two years for all SLCS equipment except valve F010, which are tested every 90 days." This statement seems to contradict the information provided in Table 4.4-3. Also, the staff could not find any reference to valve F010 in the failure data tables or the simplified line diagram. Please clarify.

GE Response

(A) NEDO-33201 Rev 2 Sections 4.4-2 and 4.4-7 provide the response to this RAI.LTR

Although the D-RAP is not yet completed, given the 8 hour LCO for train inoperability, it is inconceivable that preventive maintenance would be undertaken that would render a train unavailable. Corrective maintenance could be completed, within the same Technical Specification limitation; however, given the reliability of the system functions and the ability to sample, add solution, and recharge the nitrogen pressure without impacting operability, it is not expected that corrective maintenance would be required. All testing required by Technical Specifications that does impact operability would be performed during plant conditions not requiring system operability.

(B) NEDO-33201 Rev 2 Sections 4.4-2 and 4.4-7 provide the response to this RAI.LTR

Refer to (A) above.

(C) NEDO-33201 Rev 2 Section 4.4-7 provides the response to this RAI.LTR

There are, in fact, four manual valves: F001A&B and F006A&B. These valves are Locked Open and, as such, are considered to have no impact on performance of the system function. These valves will be verified in the appropriate position as part of a startup lineup and be strictly controlled by Operations (via key control).

The statement that their position is checked periodically is misleading as Technical Specification SR 3.1.7.5 specifically eliminates locked position valves in the flow path from the 31 day verification; however, as stated above, these valves should be part of the startup lineup verification. This verification could be construed as "periodic," but use of this terminology could cause confusion. Given the controls placed on locked position valves there is no concern on mispositioning and they are excluded from the analysis.

(D) NEDO-33201 Rev 2 Table 4.4-3 provides the response to this RAI.LTR

Table 4.4-3 was in error. F006A&B will not be tested quarterly. In fact, mention of either F001A&B or F006A&B on Table 4.4-3 has been deleted. F001A&B and F006A&B are installed only for isolation for maintenance purposes of other system components; there is no expectation that they will be "tested." They will be cycled as necessary to support maintenance activities on other system components, their position is controlled by Operations as discussed above.

(E) NEDO-33201 Rev 2 Section 4.4-4.1 provides the response to this RAI.LTR

F507A&B and F508A&B are not modeled. Their function is to aid in preventing nitrogen injection into the RPV after the SPBS has been injected, failure of this function does not impact SLCS function.

(F) NEDO-33201 Rev 2 Figure 4.4-2 provides the response to this RAI.LTR

The "working inventory make-up systems" portion of the fault tree has been eliminated; that function has no impact on performance of the SLCS to inject, it is makeup only and, though important to meeting the standby condition requirements by establishing proper solution and pressure within the accumulator, it is not used during performance of the SLCS function.

(G) NEDO-33201 Rev 2 Table 4.4-4 provides the response to this RAI.LTR

Common cause failure of Squib Valves and Check Valves, between loops, has been added to Table 4.4-4.

(H) NEDO-33201 Rev 2 Figure 4.4-2 provides the response to this RAI.LTR

Type Code UV_-CC for check valve failure to open was used with a value of 1E-4/demand, a standard value for check valves such as these. These particular valves normally hold RPV pressure from SLCS loops and would operate on injection.

(I) NEDO-33201 Rev 2 Table 4.4-4 provides the response to this RAI.LTR.

This value represents the CCF of ALL Squib Valves; the CCF was added in (G) above, it can only be assumed that only the value discussed was initially modeled due to it being the most limiting; however, all combinations are now included in the analysis.

(J) NEDO-33201 Rev 2 Table 4.4-3 provides the response to this RAI.LTR

F010 is a normally open globe valve on the discharge of Mixing Pump C002; there is no testing requirement on this valve. There is SR 3.1.7.5 which states to: "Verify each SLC System manual, power-operated, and automatic valve in the flow path that is not locked, sealed, or otherwise secured in position is in the correct position." F010 is not in the flowpath and would therefore not be verified to comply with this requirement, as would not F013, F014, F029A&B, F028A&B, F507A&B, and F508A&B that have been removed from NEDO-33201 Revision 2 Table 4.4-3.

Affected Documents

No DCD changes will be made in response to this RAI.

NEDO-33201 Rev 2 has been revised as noted in the attached markup or as described above.

NRC RAI 19.1-50

Clarify/explain how certain aspects of the Gravity-Driven Cooling System were modeled in the PRA.

The staff needs additional information, related to Section 4.6 Gravity-Driven Cooling System (GDCS) in the following areas:

(A) There is an inconsistency between assumptions #2 and #3 on page 4.6-1. Assumption #2 implies that there are three 8-inch lines (one taking suction from pools A and C) and two taking suction from pool B. Assumption #3 refers to four 8-inch lines. Please clarify.

(B) It is stated (at the bottom of page 4.6-1) that "Information regarding alarms and instrumentation is preliminary." The staff expects GE to point out any changes to this important information before the final design certification review.

(C) Please provide the basis, including major assumptions, for the success criteria associated with GDCS operation (both short term and long term cooling). Are the criteria valid for all conditions and configurations modeled in the PRA accident sequences? Please discuss.

(D) It is stated (page 4.6-2) that "The check valves prevent gross reverse back flow to the pools after the squib valves are actuated if the vessel pressure is still higher than the pool pressure plus its gravity head." In this case the check valves can fail to open (even common cause) once the vessel pressure decreases. It appears that no failure to open (individual or common cause) of check valves has been considered. Please explain.

(E) Provide the basis for not considering unavailability of one or more GDCS lines due to test and maintenance (preventive or corrective). Discuss in terms of the technical specification requirements for this system.

(F) Please explain how the probability (1.75E-3) for the failure of a check valve (to remain open or plug) was obtained. Also, provide the basis for not considering common cause failures among the various GDCS injection and equalizing line check valves (to remain open or plug). Please discuss.

(G) Please explain the assumptions and associated bases in estimating the common cause failure (CCF) factors for the GDCS squib valves. The staff notes that there is no actual operational experience with the type and size of squib valves used in the ESBWR design. The estimated CCF factor for a set of four or more squib valves by the approach recommended in ALWR Utility Requirements Document (ESBWR PRA Reference 5-1) is 4.2E-2, which is significantly higher than the 5E-3 value used in the ESBWR PRA. Please discuss. The staff believes that there is significant uncertainty associated with the CCF probability of squib valves and the impact of this uncertainty on the results and insights of the PRA should be investigated by sensitivity studies.

(H) Please explain the assumptions and associated bases in estimating the CCF factors for orifices in the GDCS injection and equalizing lines (1.44E-5) and the various I&C components supporting GDCS squib valve actuation, such as pressure and level transmitters and detectors.

GE Response

(A) NEDO-33201 Rev 2 Section 4.6-2 provides the response to this RAI.

There are 3 pools, A, B/C, and D (new numbering); there are 4 eight inch lines, two taking a suction on pool B/C and one each from pools A and D. Assumptions deleted as the design supports this as fact.

(B) NEDO-33201 Rev 2 Section 4.6-2 and Table 4.6-1 provide the response to this RAI.

Statement deleted as the expected alarms and instrumentation are now identified in design documentation.

(C) NEDO-33201 Rev 2 Section 3.2 provides the response to this RAI.

The success criteria contained in Section 3.2.

(D) NEDO-33201 Rev 2 Figure 4.6-2 provides the response to this RAI.

Individual and common cause failures of check valves are now addressed in the model.

(E) NEDO-33201 Rev 2 Table 4.6-3 provides the response to this RAI

Table 4.6-3, Component Test and Maintenance, states there is no on-line maintenance performed; all maintenance will be performed during refueling. There are no Technical Specification requirements that result in unavailability at a shorter performance interval than 24 months.

(F) NEDO-33201 Rev 2 Section 4.6.2 and Figure 4.6-2 provide the response to this RAI

The value used comes from the EPRI URD database for check valve failure to remain open or plug (UV_ OC) is 2.0E-7/hr. The specific design of the check valves in the injection path is not yet known. A conservatism of a factor of 10 with respect to the typical check valve/application is utilized in the model until more certainty can be determined

(G) NEDO-33201 Rev 2 Figure 4.6-2 and Table 4.6-4 provide the response to this RAI.

This model revision uses the CAFTA CCF tool with the MGL approach, currently the "four or more" factor (delta) is now input at 0.9. However, with the CAFTA CCF tool, the delta factor is "the probability that when 3 fail, they all fail". (H) NEDO-33201 Rev 2 Section 4.6-2 provides the response to this RAI.

There are no orifices in the injection or equalizing lines; all reference to them has been removed from the model.

Affected Documents

No DCD changes will be made in response to this RAI.

NEDO-33201 Rev 2 has been revised as noted in the attached markup or as described above.

NRC RAI 19.1-51

Provide a simplified diagram of the Fire Protection System and discuss failure probabilities and support system dependencies.

Additional information is needed on the modeling of the Fire Protection System (FPS) in the PRA. Please provide a simplified diagram for the entire system and explain how the assumed failure probabilities (events U43-SYS-FF-LPCI and U43-SYS-FF-YARD) for FPS hardware failure were calculated. Was credit taken for all three fire water pumps? Why were no CCFs considered? What testing and maintenance assumptions were made? What are the system's dependencies on support systems? Please explain.

GE Response

Complete modeling details for the Fire Protection System, including a simplified drawing, failure data, testing and maintenance assumptions, and common cause treatment are in NEDO-33201 Rev 2 Section 4.16.

Affected Documents

No DCD changes will be made in response to this RAI.

NEDO-33201 Rev 2, Section 4.16 has been revised as noted above.

NRC RAI 19.1-52

Clarify/explain how certain aspects of the Fuel and Auxiliary Pools Cooling System were modeled in the PRA.

The staff needs additional information related to Section 4.7 Fuel and Auxiliary Pools Cooling System (FAPCS) in the following areas:

(A) It is stated (page 4.7-2) that "When the FAPCS operates in the cooling mode, water is drawn from the pools listed in 4.7.1 "a" through "e" using surface level skimmers."This information is not shown in the simplified diagram (Figure 4.7-1) and the pools listed in 4.7.1 are numbered from "e" to "l." Please clarify. Also, please verify that no water can be diverted to these pools when the system is actuated for reactor pressure vessel injection operation or for suppression pool cooling operation.

(B) Please explain what components are included in common cause failure (CCF) events G21-MOV-CF-CLOSEA, G21-MOV-CF-OPENA/B and G21-ACV-CF-SUCTION and discuss how the associated probabilities were calculated. It appears that not all combinations of motor-operated valves were considered and the air operated valves are in series.

(C) Assumption #2 (page 4.7-2) states that "...the necessary measures will be taken to make air operated valves not dependent from the Instrument Air System on emergency situation." The staff needs more detailed information about the measures that will be taken to ensure proper modeling in the PRA fault trees.

(D) Explain how the probability of 3E-3 for the unavailability of one FAPCS train, due to test and maintenance, was calculated. This probability assumes that, on average,each train will be unavailable only one day per year. This is an optimistic assumption (based on operating reactor experience), especially since there are no technical specification requirements for this system. Furthermore, since the FAPCS is not made up of two completely independent trains, the single unavailability of some components (e.g., air-operated gate valve F332 in the LPSI injection line and motor-operated valve F306 in the suppression pool cooling line) cause the whole system to be unavailable. Please discuss.

(E) It is indicated (Table 4.7-3) that active valves will be tested quarterly and maintenance valves every 24 months. Please list the maintenance valves that are modeled in the PRA and explain how the failure probabilities of these valves were calculated. Also,explain the basis of the monthly rotation assumption between trains and how this assumption impacts the PRA results.

(F) Provide justification for assuming zero probability of mispositioning manual valves F308 and F320.

GE Response

NEDO-33201 Rev 2 provides the response to this RAI. The specific sections for the responses are indicated below.

(A) Typographical error fixed and pools are labeled correctly and referenced correctly. Simplified drawing (NEDO-33201 Figure 4.7-1a) shows "Spent & Aux Pools" which represent pools "a through e".

NEDO-33201 Rev 2 Section 4.7.2 – assumptions 5 & 6 state

5) FAPCS is assumed to fail if the suction MOVs from the spent & auxiliary pools fail to close (or remain closed). It would not cause loss of system function, but operators would isolate the system if the spent fuel pool level were dropping (if suction was not isolated, but injection was switched to the suppression pool, or RPV).

6) System function is assumed lost (in both modeled modes) if the return MOVs to the Spent Fuel & Auxiliary pools fail to close or remain closed. F008A/B must close to isolate FAPCS flow from diverting from the desired (SPC or LPCI) path to the other pools. One of these valves (F008A when Train A is running) is open whenever the system is in cooling/cleaning mode.

(B) Common cause has been completely redone for FAPCS. Details for these events (including the methodology, MGL factors, and component groupings) are in NEDO 33201 Rev 2 Section 5.3 and FAPCS CCF events are listed in Table 4.7-4

(C) Response is covered by NEDO-33201 Rev 2 Section 4.7.2 – assumption 11 and Section 4.7.5 'System Interfaces'.

(D) Design changes have added parallel paths for several sections of the FAPCS system. Previous design had valve F332 for LPCI. Updated design has F332A & F332B in parallel (similar changes exist for suppression pool suction valves and suppression pool cooling valves). Parallel trains allow for maintenance of one during power. Maintenance of FAPCS trains and individual components has been revised, new events and values are listed in NEDO-33201 Table 4.7-5.

(E) Response is covered by NEDO-33201 Rev 2 Section 4.7.2 – assumption 10 and Section 4.7.6 'System Testing'.

(F) F320 now has a (non-zero) failure probability. The event and failure rate are listed in NEDO-33201 Rev 2 Table 4.7-7

Affected Documents

No DCD changes will be made in response to this RAI.

NEDO-33201 Rev 2, Section 4.7 has been revised as described above.

NRC RAI 19.1-53

Clarify/explain how certain aspects of the Reactor Water Cleanup/Shutdown Cooling System were modeled in the PRA.

The staff needs additional information related to Section 4.8 Reactor Water Cleanup/Shutdown Cooling System (RWCU/SDCS) in the following areas:

(A) It is stated that one of the system purposes (third bullet on page 4.8-1) is "To provide high-pressure cooling of the primary coolant...." It is also stated (page 4.8-2): "During emergency plant conditions, the system is used in the SDC mode to relieve the Isolation Condenser System (ICS) load, that is, the standby train is aligned, and its pump is started." It appears that these statements do not completely reflect the system function modeled in the PRA event trees. In the event trees, the RWCU/SDCS is used for decay heat removal following successful passive low pressure injection. Please clarify.

(B) It appears that there are four designators used for the three air-operated containment isolation valves (F005A&B, F006A&B, F007A&B and F3A&B). Please clarify this information in the text, the tables and the simplified flow diagram.

(C) Assumption #2 (page 4.8-1) states that "...the relevant measures will be taken so that the air-operated valves do not depend on the Instrument Air System in an emergency situation." The staff needs more detailed information about the measures that will be taken to ensure proper modeling in the PRA fault trees.

(D) Please explain what components are included in the common cause failure (CCF) events G31-MOV-CF-OPENA/B, and G31-ACV-CF-DEENERGA/B and discuss how the associated probabilities were calculated. It appears that not all combinations of motor-operated valves and air operated valves, respectively, between trains were considered. In addition, explain why no CCF of air operated valves to open (e.g., F007A&B) and no CCF of check valves to open following loss of offsite power (e.g., F017A&B) were considered.

(E) Explain how the probability of 3E-3 for the unavailability of one RWCU/SDCS train,due to test and maintenance, was calculated. This probability assumes that, on average, each train will be unavailable only one day per year. This is an optimistic assumption (based on operating reactor experience), especially since there are no technical specification requirements for this system.

(F) It is indicated (Table 4.8-3) that active valves will be tested quarterly and maintenance valves every 24 months. Please list the maintenance valves that are modeled in the PRA and explain how the failure probabilities of these valves were calculated. Also,explain the basis of the monthly rotation assumption between trains and how this assumption impacts the PRA results.

(G) Please explain why no failure of the flow control valves F002A&B and F004A&B was considered.

GE Response

NEDO-33201 Rev 2 provides the response to this RAI. The specific sections for the responses are indicated below.

(A) NEDO-33201 Rev 2 Sections 4.8-1 "Functional Description" and 4.8-3.2 "System Operation" were modified to clarify system function.

(B) NEDO-33201 Rev 2 Tables, text, and diagram all now match and accurately provide modeling details for the eight (four pairs: F005A/B, F006A/B, F007A/B and F3A/B) valves.

(C) The assumption referred to in the RAI has been removed. The relevant measure taken is to have the air operated valves fail to the emergency position when an emergency position has been specified on loss of instrument air or nitrogen. The containment isolation valves F002A, F002B, F003A, F003B, F007A, F007B, F008A and F008B will close on a loss of instrument air or nitrogen. Air operated valves F004A, F004B, F019A and F019B are not required to change position in an emergency. The demand and failure to remain open failures of valves F004A, F004B, F019A and F019B have been included in the model. Modeling details for the system are shown in NEDO-33201 Rev 2, Figure 4.8-2.

(D) Common cause has been completely redone for RWCU/SDC. Details for these events (including the methodology, MGL factors, and component groupings) are in NEDO 33201 Rev 2 Section 5.3 and RWCU/SDC CCF events are listed in Table 4.8-4.

(E) NEDO-33201 Rev 2, Table 4.8-3 shows the updated 'out of service for testing or maintenance' values and lists the source of the numbers (EPRI ALWR URD, Revision 8).

(F) NEDO-33201 Rev 2, Table 4.8-3 shows the expected test interval used for the equipment in the system. Maintenance valves (manual valves) are no longer included in the model explicitly. The failure of the maintenance valves is implicitly included in the restoration errors (RE) events that have been added to the model. A quarterly assumption has been assumed for the train rotation. A review of current industry operating practices determined that generally, plants currently rotate trains on a monthly basis. Since the design does not currently address the train rotation frequency, a quarterly frequency was assumed. The impact on the PRA results is the in the restoration error (RE) event calculation. The longer the time period between train rotation, the longer a restoration error could go undetected and the higher the calculated failure probability for the restoration error event.

(G) Failure of flow control valves F004A and F004B has been added to the model. Modeling details for the system are shown in NEDO-33201 Rev 2, Figure 4.8-2, and a list of system basic events is in NEDO-33201 Rev 2, Table 4.8-7

Affected Documents

No DCD changes will be made in response to this RAI.

NEDO-33201 Rev 2, Section 4.8 has been revised as described above.

NRC RAI 19.1-54

Clarify/explain how certain aspects of the Feedwater and Condensate System were modeled in the PRA.

The staff needs additional information related to Section 4.9 (Feedwater and Condensate),in the following areas:

(A) Please explain how turbine bypass fails and how the probability of basic event N21-SYS-FF-BYPASS (1E-2) was calculated.

(B) It is stated that the air operated valve F018 fails to remain open on a loss of air supply. This failure, which fails both the power conversion system and the high pressure injection through the feedwater lines top events, was not modeled. Please explain.

(C) Please explain how the failure to open probabilities (both single and common cause) for the air-operated valves F023 and F026 were calculated.

(D) Please define the common cause failure basic event XXX-MP_-CR-SWS/CWS listed in Table 4.9-5B and explain how the probability was calculated. -12-

GE Response

NEDO-33201 Rev 2 provides the response to this RAI. The specific sections for the responses are indicated below.

(A) NEDO-33201 Rev 2 Section 4.9.2 Assumption #2 clarifies turbine bypass failure. Basic event N21-SYS-FF-BYPASS has been replaced by combination gate N21-0112-_1 that requires nine out of twelve turbine bypass valves to fail.

(B) Failure of air-operated valve F018 to remain open has been added to the model. Modeling details for the system are shown in NEDO-33201 Rev 2, Figure 4.9-2, and a list of system basic events is in NEDO-33201 Rev 2, Table 4.9-7.

(C) The failure probability for air operated valves F023 and F026 to open has been changed from 1.58E-2 to 2.00E-3 per EPRI ALWR URD Revision 8. The failure for the same valves to remain open for 24 hours has been added to the model and is 2.4E-5 per EPRI ALWR URD Revision 8. The common cause failure of valves F023 and F026 to open has also been updated. Modeling details for the system are shown in NEDO-33201 Rev 2, Figure 4.9-2, and a list of system basic events is in NEDO-33201 Rev 2, Table 4.9-7.

(D) Intersystem common cause between SWS and CWS has been removed from the model. The pumps in the two systems have several major differences.

Affected Documents

No DCD changes will be made in response to this RAI.

NEDO-33201 Rev 2, Section 4.9 has been revised as described above.

NRC RAI 19.1-55

Clarify/explain how certain aspects of the Reactor Component Cooling Water System were modeled in the PRA.

The staff needs additional information related to Section 4.10 Reactor Component Cooling Water System (RCCWS) in the following areas:

(A) Assumption #4 (page 4.10-1) states that "...relevant measures will be taken so that the air-operated valves do not depend on the Instrument Air System in an emergency situation." The staff needs more detailed information about the measures that will be taken to ensure proper modeling in the PRA fault trees.

(B) Assumption # 2 states that "All components of train A are powered from division I and those of train B from division II." However, in identifying common cause failure (CCF) of RCCWS pumps, failures referring to both trains and divisions are defined (e.g., event P21-MP_-CR-5ALL is defined as CCF to run of pumps in trains A and B while P21-MP_-CR-3A is defined as CCF of three pumps to run in division A). Please clarify the definitions of all CCFs listed in Table 4.10-5 for pumps.

(C) The definition of CCFs listed in Table 4.10-5 for the flow rate regulating air-operated valves F022A&B and F025A&B is not clear. It appears that valves considered in the same CCF group have different failure modes. No CCF of valves in different trains but with same failure mode (e.g., F025A&B) was considered. In addition, no CCF events due to loss of heat sink, which would fail two or more heat exchangers, are considered. Please clarify.

(D) It is not clear what assumptions were made in calculating the CCF probabilities listed in table 4.10-5. The information provided in Section 5 (Data Analysis) of the PRA is not detailed enough to answer the staff's questions regarding these probabilities. It appears that these CCF probabilities are significantly smaller than what one would calculate using the information provided in EPRI's "Utility Requirements Document" (ESBWR PRA Reference 5-1). Please explain.

(E) Assumption #7 (page 4.10-1) states that room cooling is not required for the first 24 hours of the accident. Please provide the basis for this statement and explain whether room cooling has been modeled for cases where the system is required to operate for longer than 24 hours.

(F) It is stated (page 4.10-9) that "...the relevant train components are checked quarterly."Please list the "relevant" train components.

(G) It appears that the failure (to remain open) of the air-operated valve F063 in the common suction line was not modeled. Please explain.

(H) Explain the basis for the probabilities of 2E-3 for the unavailability of a pump and 2.2E-3 for the unavailability of a heat exchanger. These probabilities assume unavailability of a single standby pump or heat exchanger of less than one day per year. This is an optimistic assumption (based on operating reactor experience),especially since there are two pairs of standby pumps and heat exchangers and no technical specification requirements for this system. In addition, the unavailability due to maintenance of two pumps or two heat exchangers is not unlikely. Please discuss.

GE Response

NEDO-33201 Rev 2 provides the response to this RAI. The specific sections for the responses are indicated below.

(A). The relevant measure taken is to have the air operated valves fail to the emergency position when an emergency position has been specified on loss of instrument air. The crosstie isolation valves F004, F007, F020, F027 and F061 will close on a loss of instrument air. Air operated valves F012A, F012B flow control valves for the Train A and Train B heat exchangers respectively fail open on a loss of instrument air while heat exchanger bypass valves F016A and F016B fail closed. When instrument air is lost, maximum flow is provided through the RCCW heat exchangers. F023A and F023B are the train isolation valves for Train A and Train B respectively which fail open on loss of instrument air providing maximum flow to the RCCW system. Service water supply valves P41-F004A, P41-F004B, P41-F006A, P41-F006B, P41-F009A and P41-F009B all open on a loss of instrument air to provide maximum cooling to the RCCW Heat exchangers. RCCW heat exchanger service water discharge header isolation valves, P41-F002A and P41-F002B both open on a loss of instrument air to provide maximum cooling to the RCCW heat exchangers. The demand and failure to remain in position failures of these valves have been included in the model at the appropriate locations. See NEDO-33201 Rev 2, Section 4.10.2.

(B). Assumption #2 has been deleted. Common cause is now modeled for all pumps regardless of train. See NEDO-33201 Rev 2 Table 4.10-4.

(C). NEDO-33201 Revision 2 reflects significant changes to the system and common cause. The revised model now includes cross train combinations, of air operated valves to open and of check valves to open. Groupings were done based on same valve type (gate, globe, check, AOV, MOV) and pipe size. The beta method was used and the values were calculated automatically using the application of common cause failure feature in CAFTA. The values for alpha, beta and gamma used in the calculation were obtained from the EPRI ALWR URD Revision 8, dated 3/99. The Table has been revised to be consistent with the current model. See NEDO-33201 Rev 2, Table 4.10-4.

(D). NEDO-33201 Revision 2 reflects significant changes to the system and common cause. The revised model now includes cross train combinations, of air operated valves to open and of check valves to open. Groupings were done based on same valve type (gate, globe, check, AOV, MOV) and pipe size. The beta method was used and the values were calculated automatically using the application of the common cause failure feature in CAFTA. The values for alpha, beta and gamma used in the calculation were obtained from the EPRI ALWR URD Revision 8, dated 3/99. NEDO-33201 Rev 2 Table 4.10-4 has been revised to be consistent with the current model.

(E). Assumption #7 has been deleted. RCCW room air handling units fail to start, fail to run, common cause failures and power dependencies are included in the current model. See NEDO-33201 Rev 2 Figure 4.10-2 and Table 4.10-7.

(F). Components which are modeled in the system fault tree that may be considered relevant components for the pumps are the start of the pumps and the opening of the discharge check valves. The relevant components for the heat exchangers are the RCCW heat exchanger discharge MOVs for each heat exchanger opening and the PSWS supply AOVs to each heat exchanger opening. The heat exchanger would also receive a functional leak test when it is placed in service. This subsection has been revised to clarify assumptions on system testing. NEDO-33201 Rev 2 includes a revision of Subsection 4.10.6.

(G). Valve F063 in NEDO-33201 Revision 1 has been renamed F061 in the current revision. The failure of this air-operated valve to remain open was not modeled because closure of the valve will not fail the system. Should the cross connect suction valve go closed, the Train A pumps would continue to receive water from the return header and would have the A surge tank available. The Train B pumps would continue to receive water from the return header and would have the B surge tank available. The return path has been added to NEDO-33201 Rev 2 Figure 4.10-1 to clarify the system operation and the function of the F061 valve.

(H). The probability for unavailability of a pump or a heat exchanger have been changed to 1.5E-3 and is based on the EPRI ALWR URD, Revision 8, Section A2.2. The unavailability of multiple pumps or heat exchangers was assumed to be 5% of the unavailability of a single component. The unavailability of multiple components has been modeled as basic events P21-NSC-TM-TRAINAHX, P21-NSC-TM-TRAINBHX, P21-NSC-TM-TRAINAPUMP and P21-NSC-TM-TRAINBPUMP. See NEDO-33201 Rev 2, Table 4.10-3.

Affected Documents

No DCD changes will be made in response to this RAI.

NEDO-33201 Rev 2 has been revised as described above.

NRC RAI 19.1-56

Clarify/explain how certain aspects of the Plant Service Water system were modeled in the PRA.

The staff needs additional information related to Section 4.11 Plant Service Water (PSW) system in the following areas:

(A) Assumption #1 (page 4.11-1) states " The normal supply source for the pumps is the Cooling Tower Makeup System (Y41). Upon a malfunction of this system, the cooling water supply to the exchangers is supplied from the PSW pumps." Please clarify this statement. A simplified flow diagram including both systems P41 and Y41 would be helpful. Assumption #1, also, states that "The malfunction of the Y41 system is currently represented by special event P41-SYS-FF-3CTMP in the event that the flow from two pumps is required.....and by special event P41-SYS-FF-2CTMP in the event that the flow from two pumps is required..." What is the reason for representing the failures of the Cooling Tower Makeup (CTM) system by special events? Please explain what do these special events include and how the assumed failure probabilities were calculated.

(B) Assumption #4 (page 4.11-1) states that "...the relevant measures will be taken so that the air-operated valves do not depend on the Instrument Air System in an emergency situation." The staff needs more detailed information about the measures that will be taken to ensure proper modeling in the PRA fault trees."

(C) It is stated in Table 4.11-3 that "A periodic change ...is assumed such that the relevant train components are checked quarterly." Please explain how this will be achieved and list the "relevant" train components.

(D) It is not clear what assumptions were made in calculating the CCF probabilities listed in Table 4.11-5. The information provided in Section 5 (Data Analysis) of the PRA is not detailed enough to answer the staff's questions regarding these probabilities (e.g., why the CCF to run for 2 pumps is smaller than the case of 3 pumps?).

GE Response

NEDO-33201 Rev 2 provides the response to this RAI. The specific sections for the responses are indicated below.

(A). The previous Assumption #1 has been deleted per the latest design document which does not credit the Cooling Tower Makeup system (Y41). Special events P41-SYS-FF-3CTMP and P41-SYS-FF-2CTMP are no longer included in the model because Y41 is not credited. NEDO-33201 Rev 2 Section 4.11.2 shows that this assumption has been deleted.

(B). Assumption #4 has been deleted. The current model for the PSWS does not contain any air operated valves. The PSWS air operated valves which are modeled in other systems (for example PSWS valves to and from the RCCW HXs) have had relevant measures taken to ensure the air operated valves fail to the emergency position Air operated valves fail to the emergency position when an emergency position has been specified on loss of instrument air or nitrogen. NEDO-33201 Rev 2 Section 4.11.2 shows that assumption #4 has been deleted.

(C). Current industry practices indicate monthly active component rotation is typically used. In some cases weekly rotation is used to support maintenance setup for work week planning. However, since the active component rotation has not been determined, a quarterly active component rotation has been assumed. The impact on the PRA is in the determination of restoration errors. The longer the time between rotations, the higher the probability of a restoration error. NEDO-33201 Rev 2 Table 4.11-3 shows quarterly active component rotation.

(D). Common cause has been redone in the current PSWS system fault tree model. The beta method was used and the values were calculated automatically using the application of the common cause failure feature in CAFTA. The values for alpha, beta and gamma used in the calculation were obtained from the EPRI ALWR URD Revision 8, Table A3-1 dated 3/99. The CCF probability for two pumps failing to run is now greater than the failure rate for all pumps failing to run. The mulitiplier for CCF of three out of four pumps failing to run is 0.0 in Table A3-1 of the EPRI ALWR URD Revision 8, resulting the CCF for three out of four pumps being 0.0. NEDO-33201 Rev 2 Table 4.11-5 shows current common cause events.

Affected Documents

No DCD changes will be made in response to this RAI.

NEDO-33201 Rev 2, Section 4.11 has been revised as described above.

NRC RAI 19.1-57

The staff cannot submit detailed RAIs on Section 4.12 Instrument Air System (IAS) and Service Air System (SAS) for the following reasons: 1) It appears that no fault tree for IAS was included in Revision 1 of the PRA; 2) It appears that the designators P51 and P52 (for IAS and SAS, respectively), have been used for the wrong system in the SAS fault tree and the basic event designators; and 3) Components modeled in the SAS fault tree are not shown in the simplified flow diagram or discussed in the text (e.g., air-operated valves F0110C and F008A). Please revise Section 4.12 and related Appendix B4.12 to address these issues and provide a more detailed explanation of how the assumed common-cause failure probabilities were calculated.

GE Response

Section 4.12 for the Instrument Air System and Service Air System have been revised to remove errors, mislabeling of failures or lack of labeling of components.

NEDO-33201, Rev 2, Section 4.12 provides the response to this RAI.

(1) In NEDO-33201 Rev 2, Instrument Air System (IAS) is explicitly modelled as well as the Service Air System (SAS).

(2) In the ESBWR Tier 2 DCD Chapter 19 Revision 3, the Instrument Air System (IAS) and Service Air System (SAS) are named P52 and P51 respectively. In NEDO-33201 Rev 2, the title of subsection 4.12 is changed to "Instrument Air System and Service Air System (P52 and P51) to avoid confusion.

(3) A simplified diagram for the system has been added (NEDO-33201 Rev 2, Figure 4.12-1) and every modelled component is included in the diagram. Every basic event for the system is listed in Table 4.12-7. The common cause related probabilities are discussed in Section 5.3 of NEDO-33201 Rev 2.

Affected Documents

No DCD changes will be made in response to this RAI.

NEDO-33201, Rev 2 Section 4.12 has been revised as described above.

NRC RAI 19.1-58

Clarify/explain how certain aspects of the High Pressure Nitrogen Supply System were modeled in the PRA.

The staff needs additional information related to Section 4.13 High Pressure Nitrogen Supply System (HPNSS) in the following areas:

(A) Assumption #1 (page 4.13-1) states " Instrumentation logic for the actuation of valves located in the high pressure portion ....is used for SRV operation in both designs ..."Please clarify this statement. Which are the two designs?

(B) In Section 4.13.3.1 it is stated that "[The HPNSS] Supplies nitrogen gas to essential safety-related systems inside the primary containment........the nitrogen is normally obtained from a non-safety-related gas supply..." Is the HPNSS a safety-related system? Should not the nitrogen supply to safety-related systems be safety-related,also? Is the nitrogen supply from the Nitrogen Storage Tanks safety-related? Please discuss this issue with respect to operation of the essential safety-related systems supported by HPNSS.

(C) The fault trees for loss of nitrogen supply to the high-pressure consumers (event GP54-0001_-1) and low pressure consumers (event GP54-0001_-2) do not include failures for many components shown in the simplified flow diagram or discussed in the text without any explanation (e.g., mispositioning of normally open manual valves F011 and F007A&B, failure of several check valves to remain open, failure of nitrogen bottle station valves). Please explain all important assumptions in developing the fault trees for HPNSS, such as testing, demand frequency and monitoring that are used to justify not modeling certain failures.

(D) There are four pressure control valves and several combinations of common-cause failure are possible. Please define the group of pressure control valves that are included in the common-cause failure (event P54-CPV-CF-CONTROL) and explain how the CCF probability of 1.57E-4 was calculated.

(E) Table 4.13-4 states that "Component maintenance has not been included in the model." Please explain the reason for not including unavailability of components due to test and maintenance.

(F) It is stated (Section 4.13.11) that "There are no changes to the model for operation for 72 hours other than the mission time." The staff notes that the 72 hour mission time was not included in calculating probabilities. Please explain.

(G) The staff needs more information about the automatic actuation of air-operated valve F005 and its modeling in the PRA. Please explain event E23-RMU-FC-P54F005 (ATM Valve F005 fails to trip).

<u>GE Response</u>

NEDO-33201 Rev 2 Section 4.13 provides the response to this RAI.

(A) This statement was confusing and has been revised. It was meant to describe that the reliability of the logic of actuation would be equivalent to that of the logic of the supported components. But it had no specific relevance to system PRA modelling.

(B) When the model was developed, the following constituted the safety-related equipment required for the safe and orderly shutdown of the plant or for prevention or mitigation of a design basis accident.

(1) Nitrogen storage bottles

(2) Piping, valves, and instruments connecting the nitrogen storage bottles to the outboard pneumatically operated containment isolation valves

(3) The outboard pneumatically operated containment isolation valves

(4) The containment penetrations

(5) The inboard containment isolation check valves

(6) Piping and valves connecting the inboard containment isolation check valves to the SRV ADS accumulators and IC isolation valve accumulators

All other components within the system are non-safety-related.

In the current design, the HPNSS is a non-safety-related system but provides a containment isolation function for the HPNSS piping penetrating containment. Safety related nitrogen operated valves within containment fail safe or have an accumulator with sufficient capacity to perform the safety function.

(C) The system description and system modeling have been revised. The associated system flow diagram now reflects the modeled components. The system model assumptions are listed in the system notebook.

(D) The pressure control or regulating valves are usually operating under different conditions, such as pressure or valve position (normal open vs. normal close). Also, the design has not progressed to the point of determining if these pressure regulating valves are the same. However, a sensitivity study has been performed. for valves F005 and F016. These valves are modeled assuming these pressure regulating valves fail from a common failure mechanism. The risk insight gained on these valves when additional design information becomes available can used to determine if other pressure regulating valves should be considered for common cause modeling. The common cause factors are discussed in Section 5.3 of NEDO-33201 Rev 2.

(E) Because the nitrogen supply is required to make up for operational losses, preventative maintenance is projected (and assumed in the model) to be performed during refueling outages.

The normal supply path for nitrogen from the Containment Inerting System is constantly checked upon making up for nitrogen losses produced in the supported equipment. The system is normally in operation and system health is monitored by the amount of makeup N2 that it has to supply.

The maintenance unavailability at power due to corrective maintenance is judged to be negligible. As such, unavailability due to testing and maintenance on this system is currently not included.

(F) Standard results of the PRA for a 24- hours mission time have been provided to allow comparison with other reactor PRAs. Nevertheless, certain models, such as IS and PCCS have included failures modes beyond that time frame, [IC/PCC pools makeup], to assure that a long term safe condition is quantified. In NEDO-33201, Section 11 a sensitivity analysis has been included that extends the mission time of the PRA beyond 24 hours to 72 hours and, cover both the level 1 and the level 2 PRA.

(G) The old basic event H23-RMU-FC-P54F005 represented the failure of the analog trip module that receives a low pressure signal from the pressure transmitter PT002. In the current model revision, it is believed that there is no analog trip module and any control logic related modelling is transferred to either system C62 or C63 as transfer gates.

Affected Documents

No DCD changes will be made in response to this RAI.

NEDO-33201 Section 5. 3 has been revised as described above.

NEDO-33201 Section 4.13 will be revised in a future update to reflect any risk insights gained after model quantification.

NRC RAI 19.1-59

Clarify/explain how certain aspects of the AC Electric Power System were modeled in the PRA. The staff needs additional information, related to Section 4.14 (AC Power System), in the following areas:

(A) It is stated (page 4.4-1, second paragraph) that "The low voltage AC power System supplies electric power at 480V and consists of non-safety buses that are normally powered from the PG buses...." This statement appears to contradict the statement made on page 4.14-2 that "The safety-related portion of the low voltage system consists of four Distribution Panels ...." Please clarify and explain what portion of the AC power is safety related and what that means in terms of modeling this system in the baseline PRA and the focused (RTNSS) PRA case.

(B) It is stated that the four safety-related Distribution Panels (A31, B31, C31, D31) are provided with plug-in connections for transportable AC generators. Please clarify if this was credited in the PRA to support long-term cooling requirements, including the focused (RTNSS) PRA case. -16-

(C) It is stated (page 4.14-2) that "The I&C Power Supply system is comprised of five subsystems. Four of the subsystems are supplied by power center buses A31, B31,C31 and D31.....The fifth is supplied by power center DCIS swing bus C23..."However, no further discussion of the I&C power Supply system is provided in Section 4.14 (with no mention that this system is discussed elsewhere). The staff notices that Section 4.15 discusses the Uninterruptible AC Power Supply System. Section 4.15, mentions four safety-related divisions and five non-safety-related "systems." This appears to contradict the Section 4.14 statement of five subsystems. Please clarify by revising the discussion provided in Sections 4.14 and 4.15, as necessary, and by using consistent terminology and designators.

(D) Table 4.14-5 includes CCF basic events for the Reactor Component Cooling Water (RCCW) pumps. It appears that these CCF events were discussed in Section 4.10. Are these events different than those discussed in Section 4.10? Table 4.14-5 shows that the CCF to start probability for the RCCW train A pumps is about an order of magnitude lower than the train B pumps. Please clarify. In addition, the description of CCF basic events needs to be improved to make it clear what exact group of components are included in the CCF event (e.g., need to state what event(s) refer to 13.8 kV breakers and define which and how many 480V breakers are included in the CCF events). Also, no spurious opening CCF of 480V circuit breakers is included even though in the discussion of Section 4.14.8 it is stated that this failure is judged to be negligible only for 6.9 kV and 13.8 kV circuit breakers.

(E) Please provide the basis for the assumed unavailability of the 230 kV switchyard due to test and maintenance.

GE Response

NEDO-33201 Rev 2 provides the response to this RAI. The specific sections for the responses are indicated below.

(A) The statement in NEDO-33201 Section 4.14.1 has been deleted for clarification in Rev 2. Refer to NEDO-33201 Rev 2 Section 4.14.3 for details. The isolation power centers supply

AC power from nonsafety-related systems to safety-related loads. Clarification has been documented in ESBWR Tier DCD Rev. 3 Section 8.1.5.2.1 (last paragraph on page 8.1-4).

(B) In NEDO-33201 Rev. 2, the PRA model takes no credit for such plug-in connections. The statement in Section 4.14.3.1 has been deleted in Rev 2 of NED)-33201.

(C) In NEDO-33201 Rev 2, this statement on the "I&C Power Supply System" has been deleted to reflect the DCD Rev. 3 design. This paragraph has been deleted because the Instrument & Control Power Supply System is not credited in the NEDO-33201 Rev. 2 PRA model.

(D) In NEDO-33201 Rev 2, the CCF Table has been changed to Table 4.14-4. CCF events have been updated with new models. The RCCWS CCF events are removed from this section. NEDO-33201 Rev 2 Section 5.3 lists the defined CCF groups and MGL parameters. The spurious opening failures of 480V circuit breakers are judged to be negligible. Section 4.14.8 in NEDO-33201 Rev 2 documents the exceptions to CCF modeling.

(E) In NEDO-33201 Rev 2, Table 4.14-3 provides the basis for the assumed unavailability of the 230 kV switchyard due to test and maintenance. The unavailability of the 230 kV (R10-SYS-TM-230KV) switchyard due to testing and maintenance has been calculated with a reasonable estimate of 116 hours out of service in one year, which results in a probability of approximately 0.01.

Affected Documents

No DCD changes will be made in response to this RAI.

NEDO-33201 Rev 2 Sections 4.14.1, 4.14.3, Table 4.14-3 and Table 4.14-4 implement the response to this RAI.

NRC RAI 19.1-60

Clarify/explain how certain aspects of the Uninterruptible AC Power Supply System were modeled in the PRA. The staff needs additional information, related to Section 4.15 (Uninterruptible AC Power Supply System), in the following areas:

(A) The staff could not find any lists of basic events and associated probabilities in Section 4.15 (Table 4.15-7 lists top events, instead of listing basic events).

(B) It is stated (page 4.15-1) that "There are five non-safety related ....supply systems......,while the other two receive 480 V AC and 125 V DC power and supply 120 V AC."This information is not shown in the provided one-line simplified diagrams. Please explain.

(C) It is stated (page 4.15-1) that "In the systems that are a long distance away from the DC power system batteries, the uninterruptible power can be supplied by a modularized Uninterruptible Power Supply (UPS) that includes batteries and battery chargers." Please provide a more detailed description of the modularized UPS and state whether and how was this modeled in the PRA.

GE Response

NEDO-33201 Rev 2 provides the response to this RAI. The specific sections for the responses are indicated below.

(A) The Basic event Table 4.15-7 has been updated in NEDO-33201 Rev 2.

(B) NEDO-33201 Section 4.15.3.1 has been changed to reflect the current UPS system design.

(C) In NEDO-33201 Section 4.15.3.1, this statement has been deleted since the modularized UPS is not credited in the Rev. 2 PRA model.

Affected Documents

No DCD changes will be made in response to this RAI.

NEDO-33201 Rev 2 Section 4.15.3.1 and Table 4.15-7 provide the response to this RAI.

NRC RAI 19.1-61

Clarify/explain how certain aspects of the DC Power Supply System were modeled in the PRA.

The staff needs additional information, related to Section 4.17 (DC Power Supply System),in the following areas:

(A) Design assumption #3 (page 4.17-1) states: "It is assumed that adequate cooling is needed and available in battery charger room." It appears that no failure to cool the battery charger rooms was modeled. Please explain.

(B) It is stated (page 4.17-2): "Battery rooms are served by a flow-through ventilation system....In case of loss of AC power, ...the ventilation is not needed." The staff notices that no mechanical failure of the ventilation system is discussed or modeled. Please explain.

GE Response

NEDO-33201 Rev 2 provides the response to this RAI. The specific sections for the responses are indicated below.

(A) Assumption #3 in NEDO-33201 Section 4.17.2 has been revised. The battery room ventilation is not required per the new design as described in ESBWR Tier 2 DCD Rev. 3.

(B) In NEDO-33201 Rev 2 Section 4.17.5, this paragraph has been deleted since the battery room ventilation is not required per ESBWR Tier 2 DCD Rev. 3. The assumption #3 has addressed this issue.

Affected Documents

No DCD changes will be made in response to this RAI.

NEDO-33201 Rev 2 Sections 4.17.2 and 4.17.5 implement the response to this RAI.

NRC RAI 19.1-62

Document major steps and assumptions in calculating probabilities for risk significant common cause failure events.

The staff needs more detailed information about the assumptions that were made in calculating the common cause failure (CCF) probabilities listed in Table 5.3-1. The alpha factor method is used to calculate CCF probabilities and generic alpha parameters are used for basic events for which no information is available in the databases. The generic alpha parameters are taken from three different sources with no indication which source is used for each of the CCF probabilities listed in Table 5.3-1. It appears that in many cases the estimated CCF probabilities are significantly lower than the CCF probabilities used in the AP1000 design certification for similar components. Please provide the major steps and important assumptions used to calculate CCF probabilities for events associated with Risk Achievement Worth (RAW) values of 5 or greater and for events associated with Fussel-Vesely (F-V) values of 1 percent or greater. In addition to important assumptions,this additional information should clearly state the size of the CCF group and the corresponding CCF parameters (alpha factors). Uncertainties associated with CCF probabilities for risk significant components should be evaluated and addressed by appropriate sensitivity studies.

GE Response

NEDO-33201 Rev 2 Section 5.3 provides the response to this RAI.

The alpha factor method is replaced by the MGL method in common cause modelling in this revision. The general approach described in NUREG/CR-4780 on common cause analysis is the main reference. The common cause factors and generic screened factors (MGL factor) are referenced from the EPRI document, "Advanced Light Water Reactor Requirements Document", Volume III, annex A to Chapter 1 "PRA Key Assumptions and Ground Rules".

Section 5.3 of NEDO-33201, Rev 2 discusses the MGL methodology and the attachments in section 5.3 document the common cause groups modeled in each of the systems along with their size and corresponding CCF parameters (MGL factors).

The risk importance measures of the common cause basic events with Risk Achievement Worth (RAW) values of 5 or greater and Fussel-Vesely (F-V) values of 1 percent or greater are discussed in Section 5.3 of NEDO-33201 Rev 2.

Affected Documents

No DCD changes will be made in response to this RAI.

NEDO-33201 Rev 2 Sections 4.17.2 and 4.17.5 the response to this RAI.

NRC RAI 19.1-64

Discuss "errors of commission" in the PRA. It is stated (page 6.2-2) that "Errors of commission have not been included in the ESBWR design PRA."

The staff believes that the omission of such errors needs to be justified by a systematic search to identify areas where errors of commission could occur and the introduction of appropriate design and operational features (if not already available) that essentially make such errors risk insignificant. Please discuss.

GE Response

NEDO-33201 Rev 2, Section 6.2 provides the response to this RAI.

From NEDO-33201 Rev 2 Section 6.2 "Type C: Post-Initiating Event Human Actions:"

> The nature of the passive ESBWR is such that post-initiator operator actions should not be such strong contributors to the risk profile as they are in current LWRs.
>
> The part of this group of actions that could aggravate the accident--a "commission error," i.e., an error that, when it occurs, gives rise to a situation in the plant worse than the one than would have happened if the error were of the no-action type (i.e., an omission error)--is considered insignificant when the plant has EOP (emergency operation procedures) that are symptom-based and when the EOP covers all the possible scenarios drawn in the accident sequences analysis. This was what was considered for the ESBWR PRA.
>
> Furthermore, the screening values of the HEP (human error probabilities) used at this stage are sufficiently conservative for the impact of any hypothetical commission error that may occur to be considered adequately treated at this stage.

Affected Documents

No DCD changes will be made in response to this RAI.

NEDO-33201, Section 6.2 Rev 2 has been revised as described above.

NRC RAI 19.1-65

Discuss the values of several time windows in Table 6.3-4

Please explain the reason for not including the values of several time windows in Table 6.3-4. Also, discuss the robustness of the assumed time windows for operator action.

GE Response

There are four time frames considered in the ESBWR design PRA, and the Type C HEPs are based on these time frames. Moreover, no credit is taken for actions that must be completed very quickly (that is: within a few minutes of the cue).

The three first frames come from NUREG/CR-1720 Table 20-1, items 0-4, 4-5, and 5-6. The last time frame [24 to 72 hours] is one of the newest to be generated for this type of new reactor. The screening probabilities for the three first ranges are assigned, in part, according to the time frames chosen.

The CP (Type C Procedure) cognitive values for Skill are from both the THERP NUREG/CR-1278 and from SHARP Apendice A. The Rule values are ten times greater and the Knowledge values are a hundred times greater that the base case, in the last case starting from the time available of 60 minutes. The last range (24 to 72 hours) values are ten times lower than the 24 hour time frame values. For CR (Type C recovery) the EF (error factor) is increased from 5 to 10 and the three initial time frames are considered only two, the first identical to the CP (the values are still considered conservative enough) and the rest of the values ten times greater than the ones from the CP.

The CP manual part values for Skill are from NUREG/CR-1278 and NUREG 4772. The Rule values are ten times greater and Knowledge vales are a hundred times greater than the Skill. The last range [24 to 72 hours] values are ten times lower than the above. For CR, the error factor (EF) is increased from 5 to 10.

Type C action HEP (human error probability) events are estimated in two parts: the cognitive part (diagnosis) and the manual part (action). The total HEP for an action is the sum of the two parts. The HEPs for the cognitive parts are the only ones that are affected by the time windows, which is why, in NEDO-33201 Rev 2 Table 6.3-3a some human actions (the manual part of some actions) do not have values in that column.

When they were available, the time frames were considered from the ESBWR sequence analysis report. When those were not available, time frames available to carry out human actions considered in the analysis were mostly extrapolated from ones in the SBWR.

The wide time frame range used to assess the time window for assigning the HEP in NEDO-33201 Rev 2 Table 6.3-3a (which are based on generic conservative values) makes it reasonable to think the impact of the time frame considered at this design stage is conservative.

Affected Documents

NEDO-33201 Rev 2, Table 6.3-3a has been revised as described above.