Enclosure 1, Attachment 1 to MFN 07-485

Response to Portion of NRC Request for Additional Information Letter No. 88 Related to ESBWR Design Certification Application ESBWR Probabilistic Risk Assessment RAI Numbers 19.1-96, 19.1-102 through 19.1-108 and 19.1-110 through 19.1-115

NRC RAI 19.1-96

To address thermal-hydraulic uncertainty regarding shutdown success criteria, please provide additional information (e.g., summary and results of calculations) that justifies short term and long term core cooling using (1) 2 SRVs, (2), 2 out of 8 lines of GDCS, (3) 2 out of 3 GDCS pools,(4) the opening of at least one equalizing line, and (5) the opening of 4 depressurization valves (DPVs) during Mode 5 when the reactor vessel head is on.

GEH Response

ESBWR Shutdown Mode 5 is described in NEDO-33201 Section 16.2.1.2 as; the time when:

1. heat removal requirements are transferred to the RWCU/SDCS
2. the Main Condenser and circulating water pumps are removed from service and
3. the use of the isolation condensers is terminated.

NEDO-33201 Section 16.2.1.1 assumes Mode 4 is 8 hours long with decay heat removal through the Main Condenser and/or the Isolation Condenser with the RWCU/SDCS put into service ½ hour after control rod insertion.

Thermal-hydraulic uncertainty for short term and long term core cooling in Mode 5 in the ESBWR Shutdown PRA was evaluated using MAAP406. In order to maximize decay heat, these analyses assumed that the events, loss of SDC and LOCAs, as applicable, begin 8 hours after shutdown corresponding to the assumed start of Mode 5. The mission time in the ESBWR Shutdown PRA, NEDO-33201 Section 16.2.2, is 24 hours with consideration of longer times for inventories of water and power to ensure core cooling.

The safety function of 2 SRVs in the Shutdown PRA is to depressurize or maintain depressurization of the reactor pressure vessel and to support low pressure injection using active systems. MAAP analysis indicates that 1 SRV is sufficient to depressurize the RPV to allow low pressure injection, using the FAPCS/LPCI Mode after a loss of SDC event occurring at the beginning of Mode 5 as shown in Case 1.

The safety functions of 2 GDCS lines, 2 GDCS pools, 1 equalizing line and 4 DPVs describe core cooling using passive injection systems. For these analyses, it was assumed that passive containment cooling was not operating. MAAP thermal-hydraulic uncertainty analyses for transients, such as loss of SDC, indicate that depressurization using 3 DPVs, injection using 1 GDCS injection line from 2 GDCS pools and opening the equivalent of less than 1 equalizing line prevents core damage for greater than 72 hours as shown in Case 2. It should be noted that the model used was not 1 GDCS injection line from each of the 2 GDCS pools but 1 injection line from the total of two GDCS pools.

MAAP thermal-hydraulic uncertainty analyses for LOCAs below the top of active fuel indicate that depressurization using 4 DPVs, injection using 1 GDCS injection line from 2 GDCS pools and opening the equivalent of less than 1 equalizing line prevents core damage for greater than 72 hours as shown in Case 3.

MAAP thermal-hydraulic uncertainty analyses for LOCAs above the top of active fuel indicate that depressurization using 4 DPVs, injection through 1 GDCS injection line from 2 GDCS pools and opening the equivalent of less than 1 equalizing line prevents core damage for greater than 72 hours as shown in Case 4.

MAAP thermal-hydraulic uncertainty analysis for a LOCA in the feedwater line indicate that depressurization is not required for injection using 1 GDCS injection line from 2 GDCS pools and opening the equivalent of less than 1 equalizing line to prevent core damage for greater than 72 hours as shown in Case 5. The size and elevation of the break allow the RCS to depressurize without operation of these systems.

Consideration of these thermal-hydraulic uncertainty results in the ESBWR Shutdown PRA leads to changes in the shutdown event trees/success criteria. These changes include the following:

- Addition of depressurization using 4 DPVs in Mode 5 LOCAs. Due to size and elevation of the break, depressurization is not required in LOCAs in FW lines.
- Assuming passive injection using at least 1 GDCS injection lines from each of 2 GDCS pools and 1 GDCS equalizing line, added to success criteria. The previous success criterion was at least 2 GDCS injection lines that could have been from the same GDCS pool.

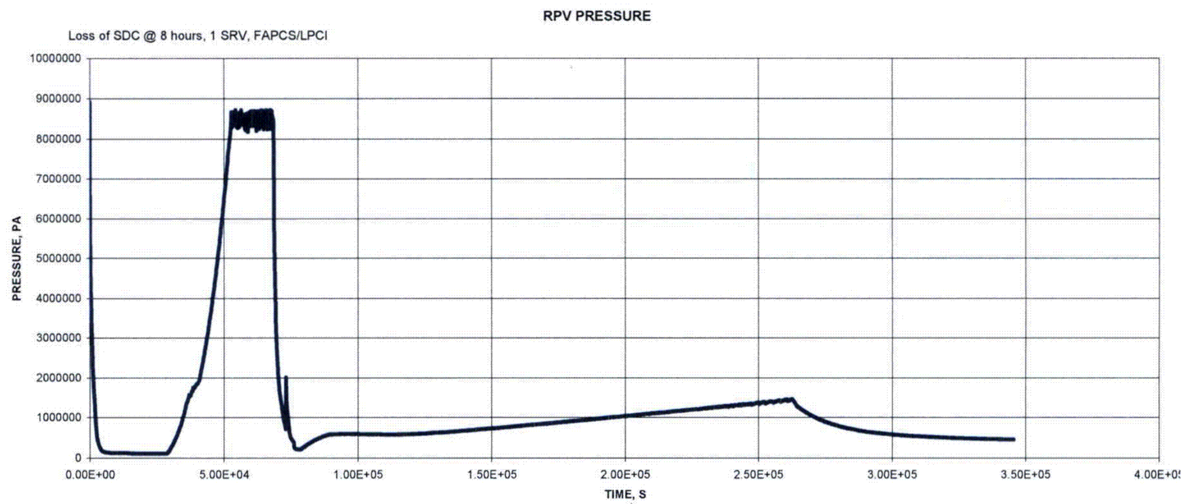
Implementing these changes in the ESBWR Shutdown PRA changes the shutdown core damage frequency from 8.77E-09/yr to 9.37E-09/yr.

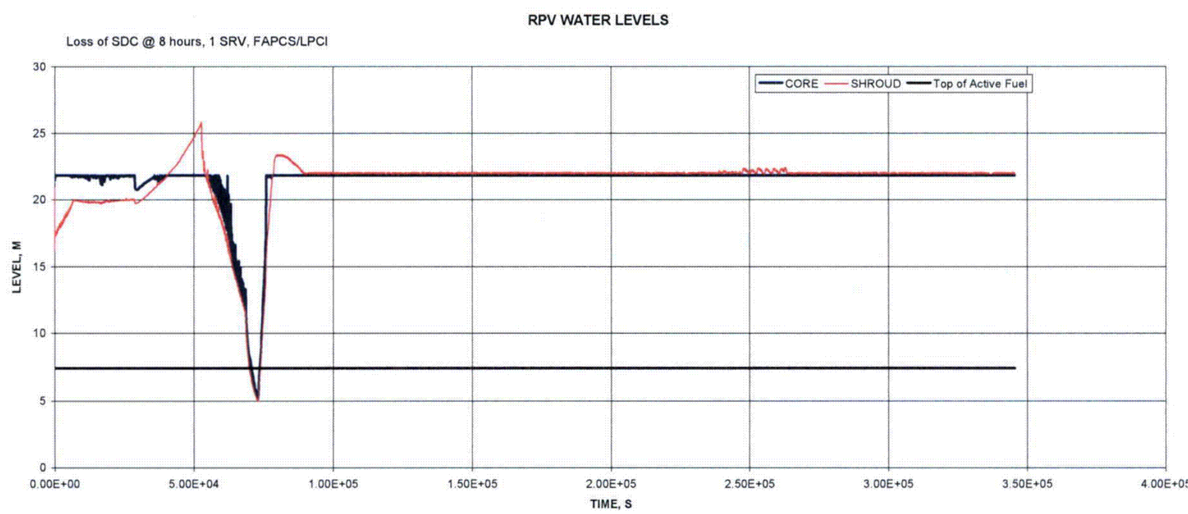
DCD Impact

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

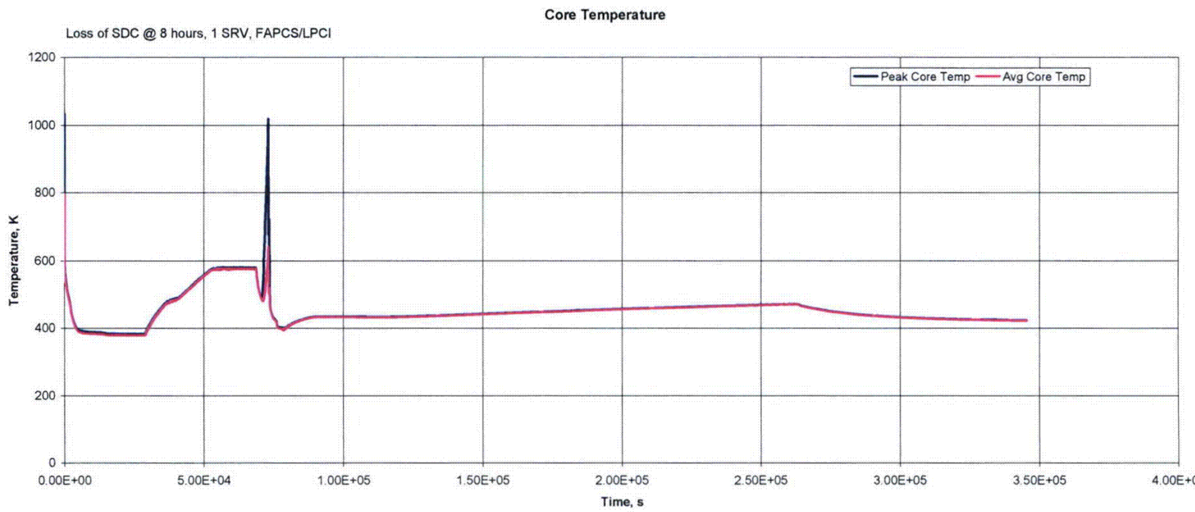
NEDO-33201, Rev 2 Chapter 16 will be updated as noted in the attached markup (Enclosure 1, Attachment 2).

Case 1: Loss of SDC @ 8 hours, 1 SRV, FAPCS/LPCI

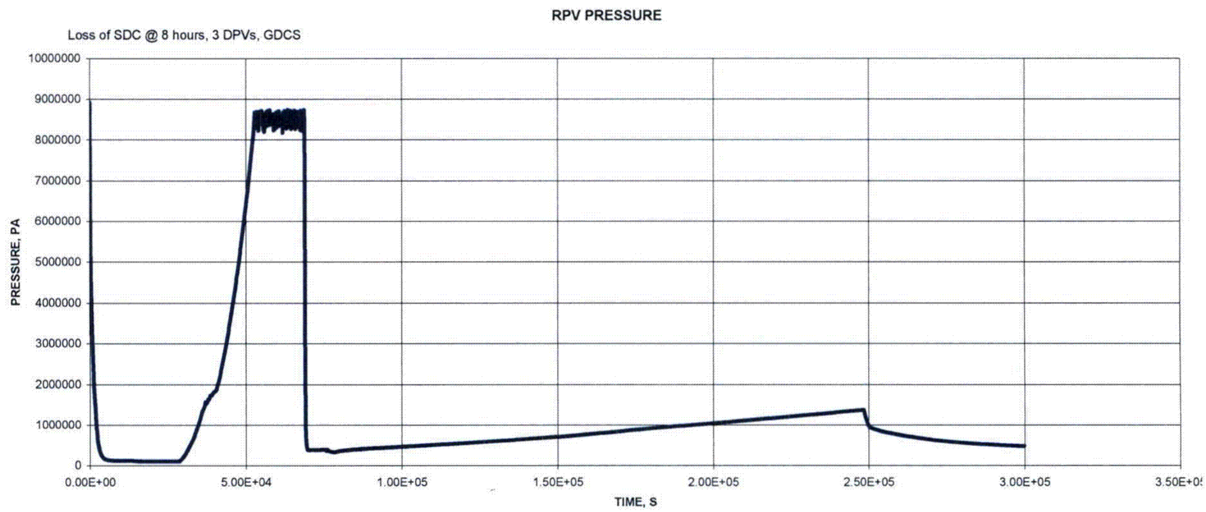


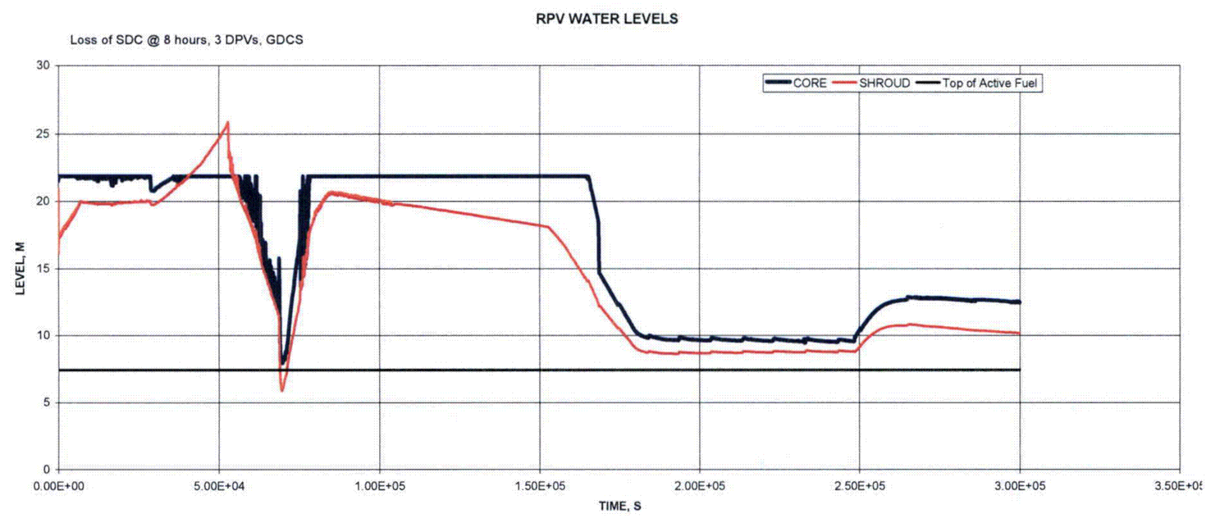


Case 1: Loss of SDC @ 8 hours, 1 SRV, FAPCS/LPCI

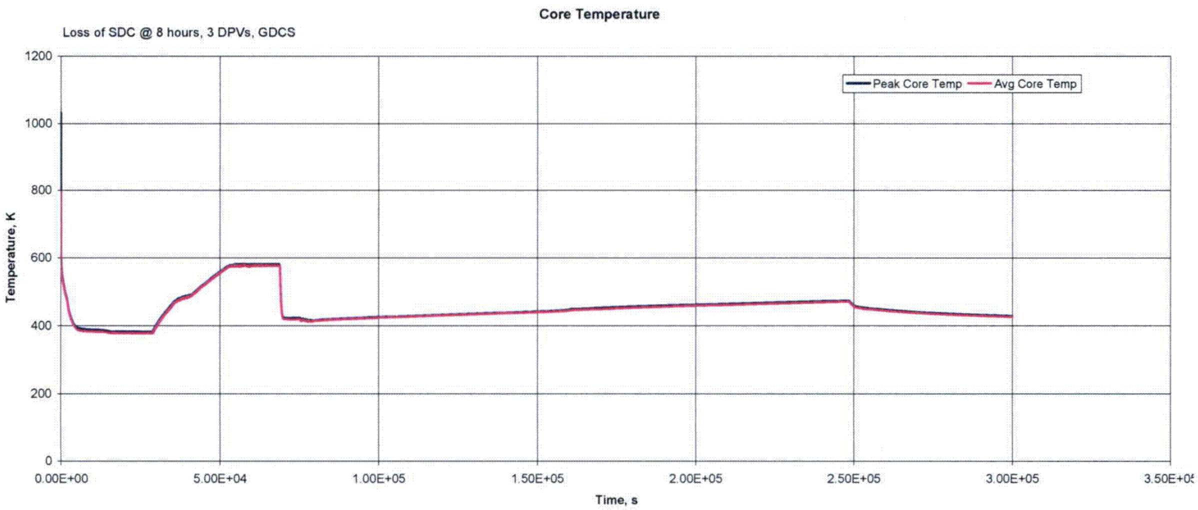


Case 2: Loss of SDC @ 8 hours, 3 DPVs, GDCS

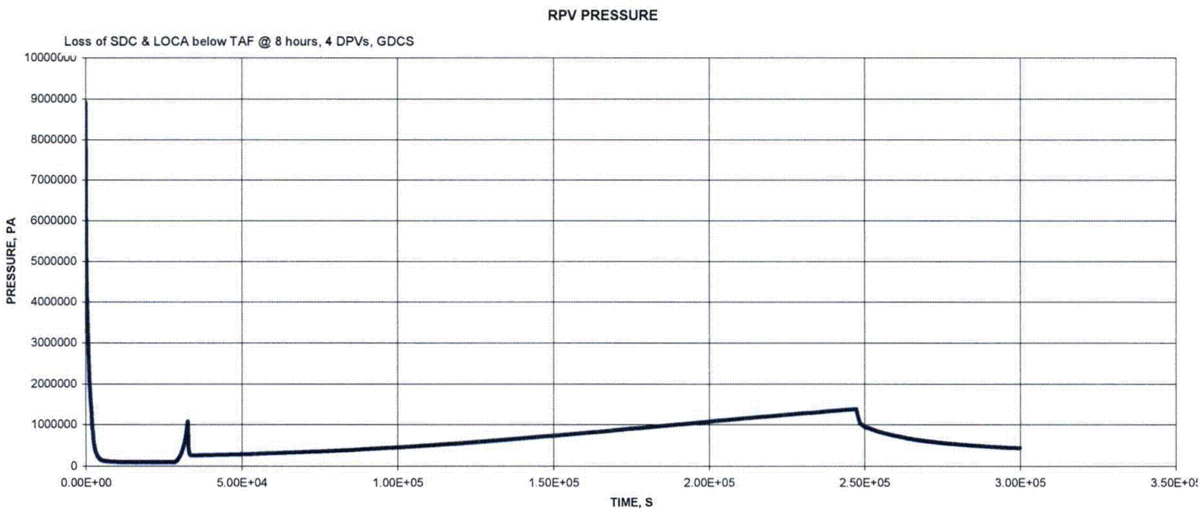


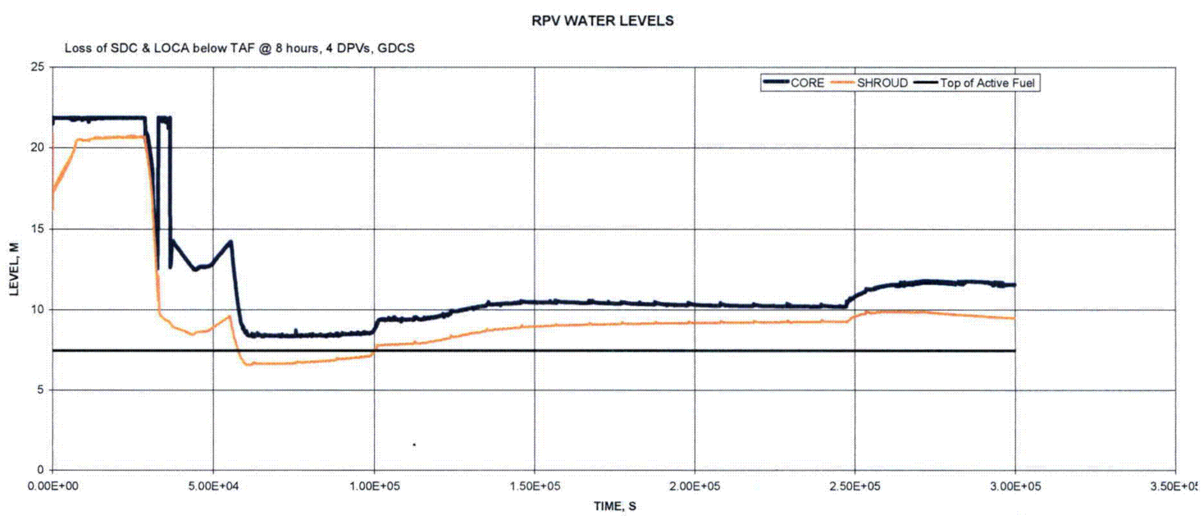


Case 2: Loss of SDC @ 8 hours, 3 DPVs, GDCS

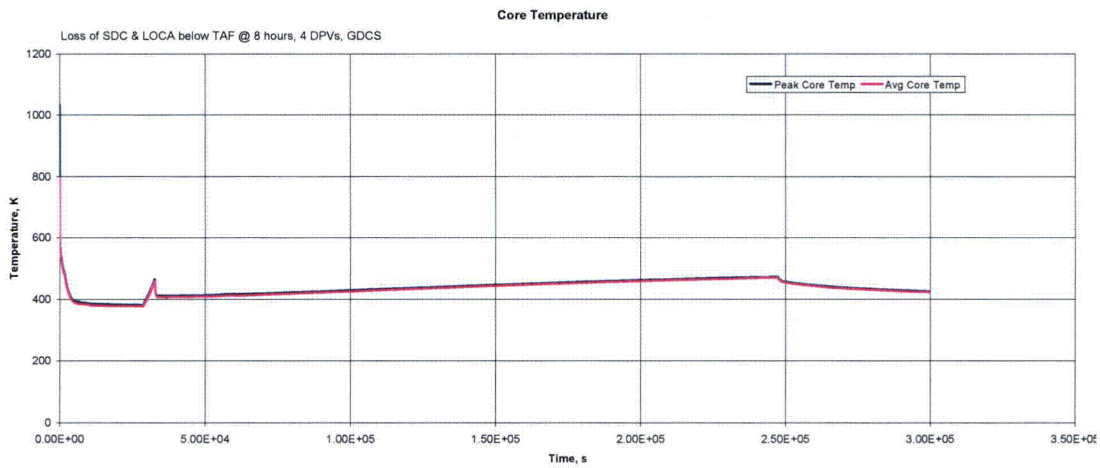


Case 3: Loss of SDC & LOCA below TAF @ 8 hours, 4 DPVs, GDCS

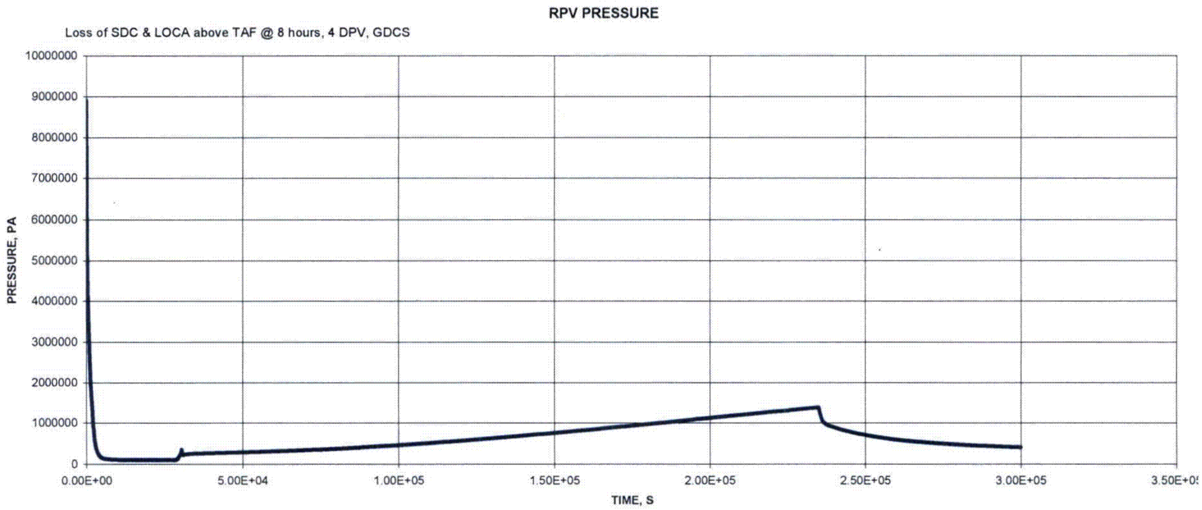


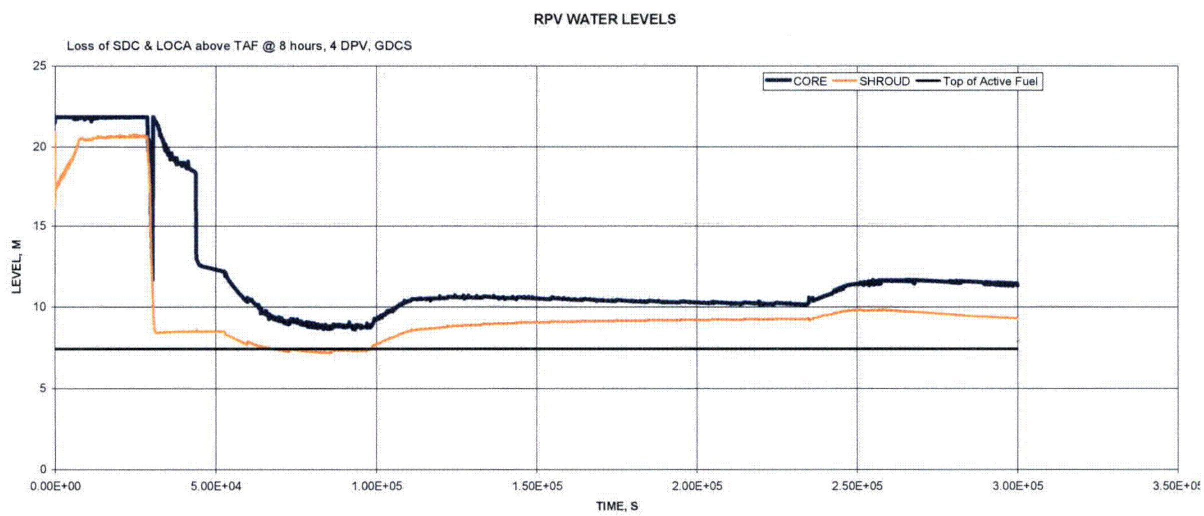


Case 3: Loss of SDC & LOCA below TAF @ 8 hours, 4 DPVs, GDCS

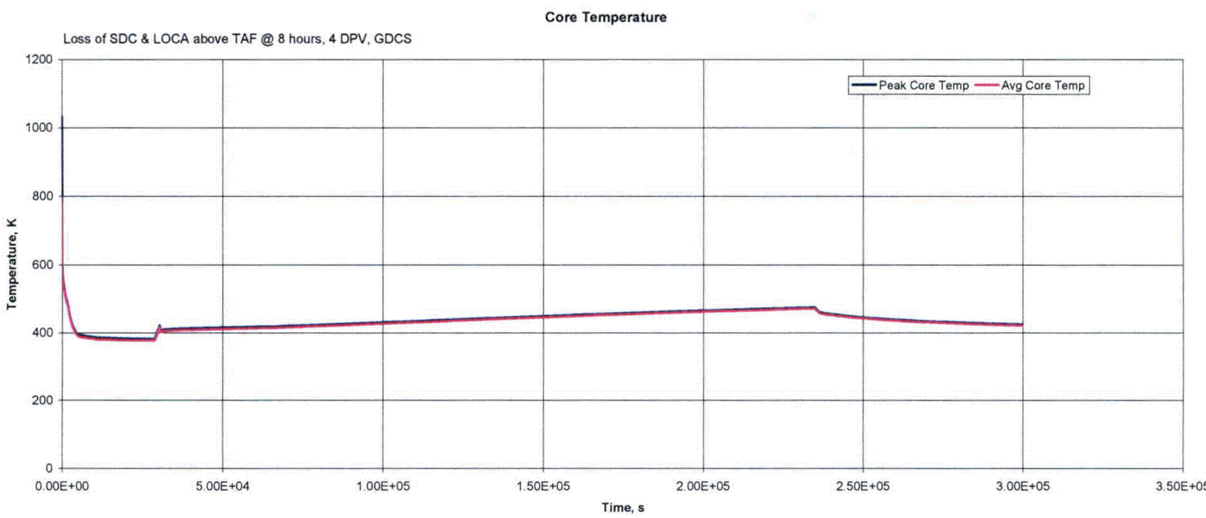


Case 4: Loss of SDC & LOCA above TAF @ 8 hours, 4 DPV, GDCS

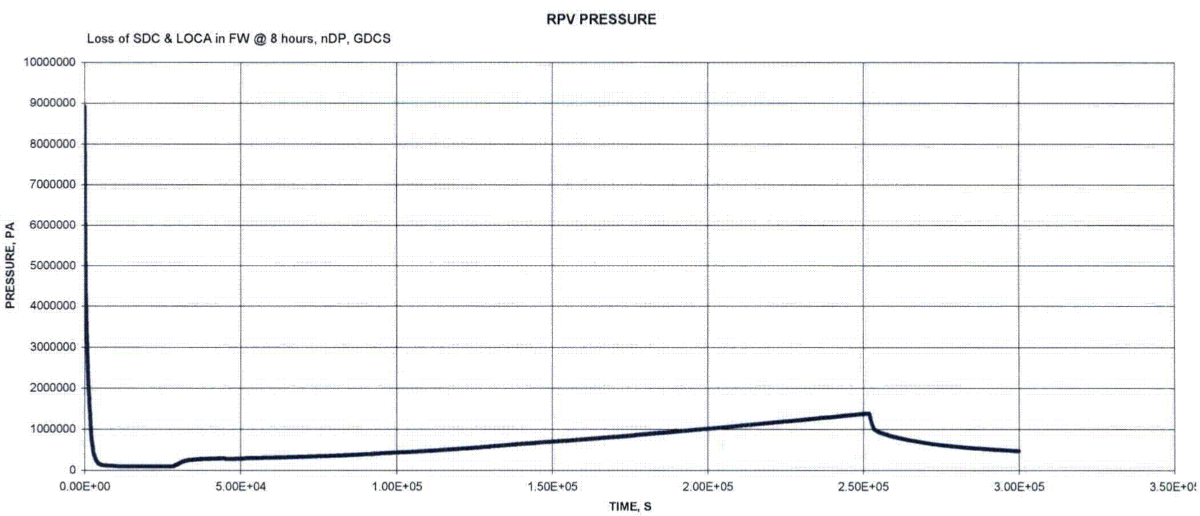


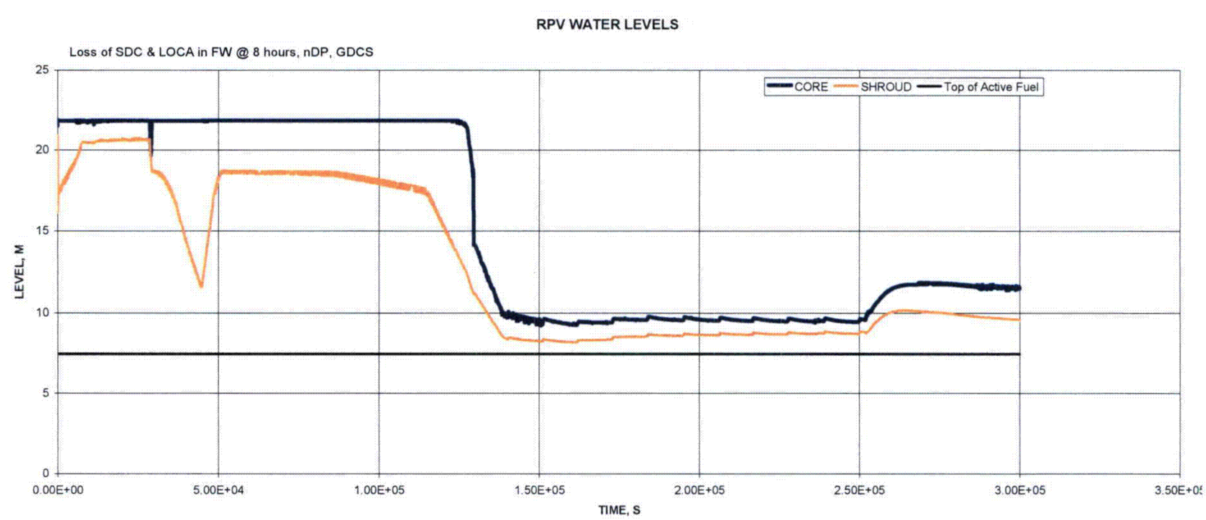


Case 4: Loss of SDC & LOCA above TAF @ 8 hours, 4 DPV, GDCS

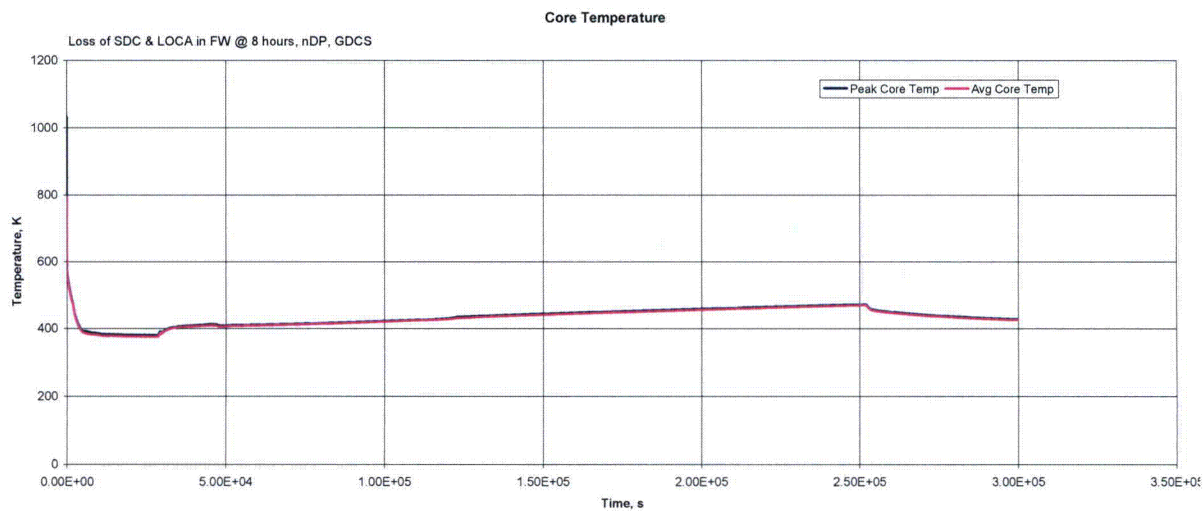


Case 5: Loss of SDC & LOCA in FW @ 8 hours, nDP, GDCS





Case 5: Loss of SDC & LOCA in FW @ 8 hours, nDP, GDCS



NRC RAI 19.1-102

Please provide (1) plant layout drawings showing flooding area boundaries, elevations and adjacent areas, as modeled in the flooding risk analysis, and (2) list of equipment credited in the PRA for accident mitigation or contributing to accident initiation that is located in each flooding area (specify whether the area includes safety-related equipment or non-safety-related equipment and include assumptions regarding cables routed through each flooding area below the maximum expected flood height). This information is needed to understand or clarify statements and assumptions made in the flooding risk analysis (Section 13).

GEH Response

Plant layout drawings showing flooding area boundaries, elevations and adjacent areas as modeled in the flooding risk analysis are provided in NEDE-33386/NEDO-33386 Revision 0.

A list of equipment credited in the PRA for accident mitigation that is located in each flooding area is provided in NEDE-33386/NEDO-33386 Rev. 0. The table specifies whether the equipment is safety related or nonsafety-related. The table identifies the equipment contributing to the accident initiation.

It is assumed that cables routed through each flooding area are not affected by flooding.

DCD/NEDO Impact

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

NEDE-33386/NEDO-33386 Rev. 0 has been created in response to this RAI. The LTR contains sensitive information supporting the flooding and fire analyses. NEDE-33386/NEDO-33386 Rev. 0 will be submitted at the end of September.

NEDO-33201 Section 13.5, Rev 2 has been revised to reference NEDE-33386 Rev. 0.

NRC RAI 19.1-103

Please provide a list of areas that were screened out from detailed flooding analysis and discuss the basis. Also, please identify any flooding sources which are located in analyzed areas but they have not been considered in the risk analysis (e.g., potential breaks in a GDCS injection line, an equalizing line, or a deluge line within the containment) and provide the basis.

GEH Response

NEDO 33201 Revision 2, Section 13 contains a table showing all areas. The table lists whether or not the area was screened out. If the area was screened out then an explanation is given explaining why the area was screened out.

A list of systems is provided in NEDO 33201 Revision 2, Section 13 with the reason, if applicable, that the system was not considered in the detailed flood risk analysis.

DCD/NEDO-033201 Impact

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

NEDO-33201 Section 13, Rev. 2 has been revised as described above.

NRC RAI 19.1-104

In Section 13, the assumed flooding frequencies (for each flooding area) appear to be based on the frequency of a "limiting" source and not all sources of water. For example, it is stated (page 13.2-1) that "The frequency of flood scenarios ...are based on generic information......The systems inside each building that could represent a flood source are considered. From these systems, the building flood source that presents the most critical characteristics for flood progression and which has the capacity to damage mitigation equipment is chosen." Also, in Table 13-1 it is stated that the frequency of flooding in the Turning Building is based on a Cooling Water System (CWS) break.

The staff believes that the flooding frequency should be based on all potential sources in each area and not just the source that causes the most damage (such assumption is adequate for the bounding treatment of the consequences of flooding). Please explain and clarify, as necessary.

GEH Response

NEDE- 33386 Revision 0 includes all unscreened flooding sources that are located in unscreened areas. Flooding initiating event frequency in the flooding zone is based on pipes, pumps, valves, tanks, heat exchangers and expansion joints within the flooding zone.

DCD/NEDO-033386 Impact

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

NEDE-33386/NEDO-33386 Rev. 0 has been created in response to this RAI. The LTR contains sensitive information supporting the flooding and fire analyses. NEDE-33386/NEDO-33386 Rev. 0 will be submitted at the end of September.

NEDO-33201 Section 13.5, Rev 2 has been revised to reference NEDE-33386 Rev. 0.

NRC RAI 19.1-105

The assumptions on page 13.2-1 include several (# 13, 15, 16, and 18) related to environmental qualification of electrical components, such as cables, connections, terminations, and junction boxes. No failures (with limited exceptions) of environmentally qualified electrical components, due to spraying or immersion, is considered in the flooding risk analysis. Please clarify and provide the basis for assuming that flooding-induced failures of environmentally qualified electrical components are negligible.

GEH Response

Inside containment, only environmentally qualified equipment is not considered vulnerable to flooding. The post-LOCA environment in containment is more severe than the flooding environment. Therefore, failures from spray or immersion of environmentally qualified equipment located inside containment are not considered in the flooding analysis.

DCD/NEDO-033201 Impact

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

NEDO-33201 Section 13, Rev. 2 has been revised as described above.

NRC RAI 19.1-106

On page 13.5-3 is stated that "The main steam and feedwater pipes are located in the steam tunnel. The water released by these breaks propagates toward the Turbine Building without affecting components located inside the Reactor Building. Therefore these flooding scenarios are addressed in the Turbine Building analysis..." Please explain the design features (e.g., watertight steam tunnel capable to withstand the maximum anticipated hydrodynamic loads) which ensure that water from a break in main steam and feedwater pipes will be directed to the Turbine Building.

GEH Response

NEDO 33201 Revision 2, Section 13 includes flooding from the main steam and feedwater pipes located in the steam tunnel propagating to the reactor building. The steam tunnel is Room 1770 and is located in flood area RB+17500. Flooding from this room is modeled as propagating to Flood areas RBA-11500 and RBB-11500.

DCD/NEDO-033201 Impact

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

NEDO-33201 Section 13 Rev. 2 has been revised as described above.

NRC RAI 19.1-107

For each flooding area considered in the flooding risk analysis (Section 13), please discuss the maximum expected flood height, flood propagation potential (e.g., through penetrations, open doors or under doors and down stairwells), and the location of equipment with respect to the maximum expected flood height.

GE Response

In general the maximum expected flood height is not critical since no credit is provided for operation of equipment in a zone which has been flooded by unscreened flooding sources unless the equipment has been environmentally qualified. Therefore, since there is no critical flood height assigned to the flood zones, the maximum expected flood height is not required.

When flood sources were screened because the capacity of the system was insufficient to affect PRA related equipment, the location of equipment was assumed to be 1 foot above the floor.

Flood propagation is through doorways and stairwells. These were used since they are able to propagate large volumes of water sufficient to overwhelm the sump pumps/ equipment drain pumps. No propagation through penetrations has been defined.

The location of equipment with respect to the maximum flood height is assumed to be below maximum flood height, which means no credit is provided for equipment in the flood area.

DCD/NEDO-033201 Impact

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

NEDO-33201 Section 13, Rev. 2 has been revised as described above.

NRC RAI 19.1-108

Please explain the basis of the assumption (page 13.5-7) that floods caused by breaks in several of the support systems (e.g., Plant Service Water System) have the same consequences as failure of the systems themselves and, since the consequences were already considered in the internal events analysis, such events are not further analyzed in the flooding analysis.

GEH Response

NEDO 33201 Revision 2, Section 13 will delete this assumption because it no longer applies. Breaks in support systems like service water, RCCW and TCCW have been considered in the internal flooding analysis.

It should be noted that quantification is not performed for all systems considered in the internal flooding analysis. One of the screening criteria applied was the removal from further consideration of systems which did not have sufficient capacity to cause flooding that would result in a plant trip or affect PRA related equipment. For example, the surge tank on the Balance of Plant Chilled Water System has an assumed capacity of 4227 gallons. Once the surge tank is empty, the pump will not have adequate NPSH and will not continue to provide water to the Balance of Plant Chilled Water System. The turbine building flooding area TB-1400 has an area of approximately 45,000 square feet. The depth of water in the turbine building as a result of the Balance of Plant Chilled water system depositing 4,227 gallons is not enough to cause a plant trip or affect PRA related equipment.

DCD/NEDO-033201 Impact

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

NEDO-33201 Section 13, Rev. 2 has been revised as described above.

NRC RAI 19.1-110

For the flooding PRA (Section13, operation at power), please provide the risk importance measures for non-safety-related systems that were credited in the flooding risk assessment. The conservative assumptions used in the flooding risk analysis do not provide insights regarding the importance of non-safety-related systems to mitigate accident sequences initiated by flooding events.

GEH Response

The risk importance measures for nonsafety-related systems that are credited in the flooding risk assessment have been calculated for the full-power flooding PRA model. The results are included in revision 2 of NEDO-33201 Section 13.

DCD/NEDO-033201 Impact

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

NEDO-33201 Section 13, Rev. 2 has been revised as described above.

NRC RAI 19.1-111

Please clarify how a break in the circulating water system (CIRC) is isolated. (e.g., number of automatically actuated valves that can isolate the break). Please explain why the probability for the failure to isolate the break used in the quantification (event tree of Figure 13-2) is an order of magnitude smaller than the probability of the same event reported in Table 13-4.

GEH Response

The circulating water pumps are tripped and the pump isolation valves and condenser isolation valves as well as the circulating lines interconnecting valve are closed in the event of a system isolation signal from the turbine building condenser area high water level switches. Successful isolation of the break occurs if the pump is tripped or the associated discharge isolation valve for the pump is closed. In addition, the condenser isolation valves which are also closed may isolate the break depending on break location. For example if a circ water expansion joint located by the condenser were to fail, the leak could be successfully isolated if the pumps trip or the discharge valves for the pumps close or the condenser isolation valves close.

Level switches are provided in the turbine building condenser area and the water level trip is initiated upon high level detection. A turbine building condenser area high level alarm is provided in the control room prior to reaching the trip level setpoint. A reliable logic scheme is used (e.g., two-out-of-three logic) to minimize potential for spurious isolation trips. For those sequences which have a large circulating water initiator, the cutsets were multiplied by 0.01 to account for the failure of the automatic trip system.

The probability for the failure to isolate the break used in the quantification (event tree of Figure 13-2) and the probability of the event reported in Table 13-4 from NEDO 33201 Revision 1, Section 13 is not used in NEDO 33201 Revision 2, Section 13.

DCD/NEDO-033201 Impact

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

NEDO-33201 Section 13, Rev. 2 has been revised as described above.

NRC RAI 19.1-112

Please provide more detailed insights gained from the flooding risk analysis by linking the results and assumptions of the analysis to specific features of the design and planned operation. Insights from the flooding analysis which are reported in Section 13.7 are high level. The staff needs detailed insights about specific design and operational features to support the design certification.

GEH Response

Insights gained from the flooding risk analysis have been provided in NEDO-33201 Section 13, Rev. 2.

DCD/NEDO-033201 Impact

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

NEDO-33201 Section 13, Rev. 2 has been revised as described above.

NRC RAI 19.1-113

Address assumptions in seismic margins risk analysis (Section15). Please discuss the assumptions related to the seismic event and fault trees. The assumptions should provide the basis for ensuring that all important seismic and mixed (seismic and random) scenarios are addressed. Explain why no seismicallyinduced LOCAs (various sizes and locations) or loss of preferred power transients were considered in the analysis. Explain why no seismic failure of I&C components are considered. It appears that important assumptions about the seismic capacity of several structures, systems and components (SSCs) are not listed in Table 15-11 and are not shown explicitly in the seismic fault trees. For example, it is stated (page 15.4-3) that "Failure of the standby liquid control system (SLCS) is dominated by failure of two components: squib valves and boron supply tanks." This implies that other SLCS SSCs are assumed to have higher seismic capacities. In addition, please include the High Confidence of Low Probability of Failure (HCLPF) values in Table 15.4-3 for SSCs for which assumptions are made in the seismic analysis.

GEH Response

For the Seismic Margin Assessment, the main methodology assumptions are based on EPRI Report NP-6041, "A Methodology for Assessment of Nuclear Power Plant Seismic Margin".

Fundamentally, the most important assumption is that, given a plant having a seismic capacity of at least one and two-thirds times the design basis safe shutdown earthquake (SSE), there will be a high confidence of low probability of failure (HCLPF) for the plant to survive without core damage.

A second assumption is that a core damage sequence based HCLPF would be insightful enough to demonstrate an adequate probabilistic risk based seismic margin.

Though EPRI Report NP-6041 recommends the seismic margin earthquake (SME) in the seismic margin assessment (SMA) should be the NUREG/CR-0098 median shape curve anchored to 0.5g peak ground acceleration, the ESBWR SME in the SMA is, as discussed in section 15.3 of NEDO-33201, the single envelope design spectra anchored to a 0.84g peak ground acceleration. This is a composite spectrum of Reg. Guide 1.60 site-independent ground spectra and site-specific performance-based design ground spectra. For sites where only generic ground spectra apply, the design spectra would possess intrinsic seismic margin capacity.

For sequence level seismic margin capacities, event trees and fault trees are presented in Chapter 15 of NEDO-33201 for at-power and shutdown plant conditions. The event trees and fault trees lead to seismic margin capacity insights from sequence level qualitative HCLPF assessment with quantitative HCLPF representations.

With regard to component level, including I&C components, at this stage of the ESBWR design, insufficient information exists to derive specific component HCLPF value; only minimum HCLPF value of one and two-thirds times SSE are presented for components in Chapter 15 of NEDO-33201. A COLA action item in Section 19 of Tier 2 of the DCD requires specific HCLPF verification at the COL stage. This approach is in line with the EPRI guideline presented in the ALWR Utility Requirements Document where an as-built engineering walk-down (assessment) is required to verify that the assumptions made in the SMA are valid. If the

as-built seismic margin assessment shows unacceptable as-constructed HCLPFs, components may require strengthening.

Regarding the statement of "Failure of the standby liquid control system (SLCS) is dominated by failure of two components: squib valves and boron supply tanks", the statement was not clearly supported and will be removed in Rev 2 of Chapter 15 of NEDO-33201. The system fault tree, with the failure of piping, check valve and motor operated valves, will continue to be presented in the section.

For a LOCA event, a seismically induced break outside containment (BOC) in the RWCU line will be included in the Rev 2 of Chapter 15 NEDO-33201 for the at-power condition. Though seismically qualified, the inclusion of the RWCU system break outside containment presents a seismic margin capacity insight, especially given the the high CDF contribution of the BOC in the RWCU line among the LOCA events.

The insight of a loss of preferred power event is already included in the shutdown seismically induced event tree as stated in section 15.4.2, Shutdown Analysis.

DCD/NEDO-033201 Impact

No DCD changes will be made in response to this RAI.
NEDO-33201, Section 15, Rev. 2 has been revised as described above.

NRC RAI 19.1-114

Clarify human actions and random failures in seismic margins risk analysis (Section15). Please clarify the discussion (page 15.4-2) regarding screening out human actions and random failures. It is stated: "Human actions are required only in the long term and......do not dominate system failure. As such, random failures are assumed to be non-significant .... " Please discuss whether any human actions are credited in the long term to recover from seismic failures and explain the correlation with the statement that random failures are not significant.

GEH Response

The random failures stated in NEDO-33201 Section 15.4-2 refer to non-seismic failures and human errors.

In the current Seismic Margin Analysis, as documented in NEDO-33201, Section 15, random failures are not credited in the long term to recover from seismic failures.

Typical industry Seismic Margin Analyses do not directly take into account non-seismic failures, human errors or the success of human recovery actions.

Random failures can be considered in a Seismic PRA or a Seismic Margin Analysis CDF estimation method. However, Section 15 of NEDO-33201 uses the current, commonly adopted industry practice of a Seismic Margin Analysis without a CDF calculation or estimation.

Industry study has shown relatively low significant contribution of random failures to seismic CDF. For instance, in the study performed for Catawba Station, as documented in EPRI Report 1003121, it showed that at least for Catawba, the non-seismic failures (excluding diesel generator system random failure to start) had a relatively negligible effect to the overall risk. The study also showed that, the effect of human actions to Catawba seismic CDF "is not considered significant" and "would not warrant a methodology where an explicit characterization of the human factors risk based on the internal events PRA results would be warranted".

The intent of the current Seismic Margin Analysis, as documented in Section 15 of NEDO-33201, is to demonstrate the ESBWR, as designed, has a seismic margin capacity of greater than the reference level earthquake on the representative failure sequences. This approach is more insightful than the simple screening method of assessing just success paths. It is deemed that the seismic induced failures and the SSCs credited in the representative accident sequences serve adequate insights on design seismic margin capacities without crediting non-seismic failures and human actions.

DCD/NEDO-033201 Impact

No DCD changes will be made in response to this RAI.
No NEDO-33201 sections are impacted.

NRC RAI 19.1-115

The statement (page 15.4-2) that only passive safety systems are credited in the seismic event tree of the seismic margins risk analysis is confusing. The seismic event tree for operation at power (Figure 15.2) includes the Fire Protection System (FPS) pump, which is not passive but has its own dedicated diesel generator. Please clarify and list HCLPF values for pump supporting equipment and piping.

GEH Response

The statement that only passive safety systems are credited has been revised to say that most of the systems credited in the seismic event tree are passive systems.

The Fire Protection System (FPS) is not considered a passive system. However, a seismic category I qualified diesel fire pump is included in the Seismic Margin Analysis.

Much of the FPS system is seismically qualified. For instance, the FPS system includes the seismic category I qualified piping and valves including supports (source of makeup water to IC/PCC and fuel pools); the primary fire water storage tanks; the fire pump enclosure; and the primary nuclear island diesel-driven fire pump and primary diesel fire pump fuel tank. For seismic category II (motor-driven fire pump) or most of the non-seismically qualified portions of the FPS system, a quality assurance program meeting the guidance of NRC Branch Technical Position SPLB 9.5-1 (NUREG-0800) is applied to the protection system. Also, special seismic qualification requirements are applied. DCD Rev 4, Table 3.2-1 lists detailed seismic classification requirements.

As stated in Rev 2 of NEDO-33201, Section 15, the HCLPF values for pumps supporting equipment and piping are referenced at a minimum seismic capacity of 1.67*SSE approach.

This approach is in agreement with industry focused scope Seismic Margin Analysis (SMA) methodology, where a minimum seismic level exceeding the plant seismic design basis is assigned.

DCD/NEDO-033201 Impact

No DCD changes will be made in response to this RAI.
NEDO-33201 Section 15, Rev 2 has been revised as indicated above.