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Subject: [External_Sender] December 1, 2015 Update to NEI 12-06 - Appendix H
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Mo/Nick/Eric,

Attached is an update to Appendix H consistent with our discussion on November 17. We will also be submitting comments on the NRC ISG next week that include similar language for seismic.

We look forward to our discussion on December 17 and gaining NRC acceptance to enable the seismic MSAs to begin.

Thanks,
Andrew

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NEI 12-06 APPENDIX H

H.1 INTRODUCTION

The purpose of this appendix is to provide guidance for a Mitigating Strategies Assessment (MSA) of the impact of reevaluated seismic hazard information developed in response to the U.S. Nuclear Regulatory Commission's (NRC) "*Request for Information Pursuant to Title 10 of the Code of Federal Regulations 50.54(f) Regarding Recommendations 2.1, 2.3, and 9.3 of the Near-Term Task Force Review of Insights from the Fukushima Dai-Ichi Accident"* [1] and the modification of existing or the development of new mitigating strategies if necessary to mitigate the effects of the reevaluated seismic hazard information. The guidance for performing an MSA for the reevaluated seismic hazard information is being included as an appendix in NEI 12-06 because the mitigating strategy approach to addressing this information makes use of the work done for the FLEX strategies.

In this appendix the reevaluated seismic hazard information will be referred to as the Mitigating Strategies Seismic Hazard Information (MSSHI). The MSA process is illustrated in Figure H.2.

The FLEX strategies [2] assumed an extended loss of alternating current (AC) power (ELAP) with a loss of normal access to the ultimate heat sink (LUHS) from an unspecified event. Sections 2 and 3 establish the boundary conditions and initial assumptions used for developing these strategies. In addition, Section 3 provides key considerations in the development of the strategies. Sections 4 through 11 establish the reasonable protection requirements for on-site FLEX equipment.

The MSA determines whether the FLEX strategies developed [2] can be implemented for the MSSHI. If it is determined that FLEX strategies [2] cannot be implemented for the MSSHI, the MSA considers other options such as performing additional evaluations, modifying existing FLEX strategies, or development of alternate mitigating strategies (AMS) that addresses the MSSHI.

Licensees will use the guidance for performing an MSA in this Appendix to do the following:

- Confirm FLEX strategies can be implemented considering the impacts of the MSSHI, or
- Develop and implement modifications necessary to ensure the FLEX strategies are able to address the MSSHI; or
- Develop and implement AMS that are able to address the MSSHI.

A brief description of this process (and the associated sections in this appendix) is as follows:

- Section H.2 – this section guides the characterization of the MSSHI.
- Section H.3 – this section guides the comparison of the seismic hazard used to develop the FLEX strategies with the MSSHI to determine if the MSSHI is bounded.
- Section H.4 – this section provides guidance for the evaluation of FLEX strategies with respect to the MSSHI.

- Section H.5 – this section provides performance criteria used to establish adequate seismic ruggedness requirements for structures, systems, and components (SSCs) that support the FLEX strategies.
- Section H.6 – this section provides requirements for documentation of the results.

H.2 CHARACTERIZATION OF THE MSSHI

The MSSHI is the licensee's reevaluated seismic hazard information at the plant's site, developed using probabilistic seismic hazard analysis (PSHA). It includes a performance-based ground motion response spectrum (GMRS), uniform hazard response spectra (UHRS) at various annual probabilities of exceedance, and a family of seismic hazard curves at various frequencies and fractiles developed at the plant's control point elevation. Licensees typically submitted the MSSHI including the UHRS, GMRS and the hazard curves at their plants to the NRC in March 2014 (or March 2015 for Western US sites), in response to the NRC 50.54(f) letter dated March 12, 2012 [1]. The MSSHI that the NRC staff found acceptable should be used in the development of the MSA. Figure 1 below describes the use of GMRS, UHRS and/or seismic hazard curves for the various MSA paths described in Section H.4.

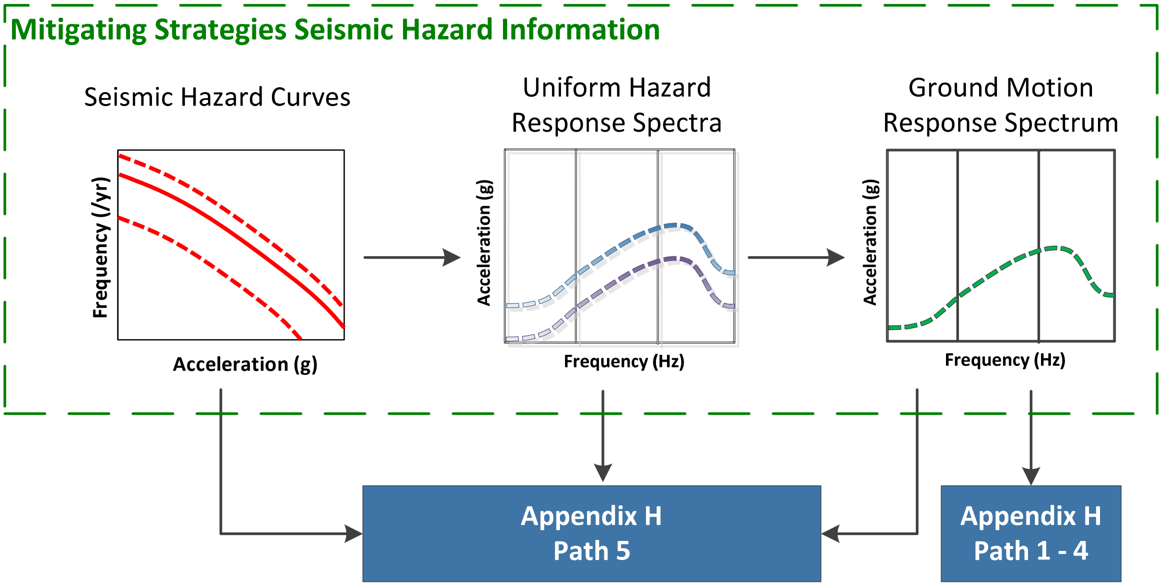

Figure H.1: MSSHI Use for Appendix H Paths

As shown in Figure H.1, the GMRS curve is used in paths 1 through 4. The hazard curves are used, in addition to UHRS and GMRS, in Path 5 when the MSA is based on a probabilistic evaluation such as a seismic probabilistic risk assessment (SPRA). Detailed descriptions of the use of MSSHI for each of the five paths are discussed in the sections below.

H.3 APPROACH FOR COMPARISON OF EXISTING SEISMIC DESIGN BASIS / PLANT CAPACITY TO MSSHI

This section provides the approach for comparing the GMRS (consistent with the screening criteria in Electric Power Research Institute (EPRI) 1025287 [3]) to the seismic design basis spectrum used for developing the FLEX strategies. The term safe shutdown earthquake (SSE) is defined in Appendix A to 10 CFR Part 100 and the site-specific SSE[1] response spectra are described within the safety analysis reports of plants. SSE is used in this appendix as the FLEX strategies seismic design basis for plant equipment. For Path 3, the GMRS is compared to a plant capacity spectrum derived from the individual plant examination of external events (IPEEE) program using the plant's high-confidence-of-low-probability-of-failure (HCLPF) capacity. The development of the IPEEE HCLPF spectrum or IHS is described in Section 3.3 of EPRI 1025287 [3].

The GMRS at frequencies 1 Hz and higher is compared to the SSE (and IHS for Path 3) to determine whether the SSE (or IHS for Path 3) bounds the GMRS, or identify any areas of exceedance of the SSE (or IHS for Path 3). The results of the comparison are used as input to the evaluation of FLEX strategies in Section H.4. The process for determining the appropriate MSA process is illustrated in Figure H.2 and described below.

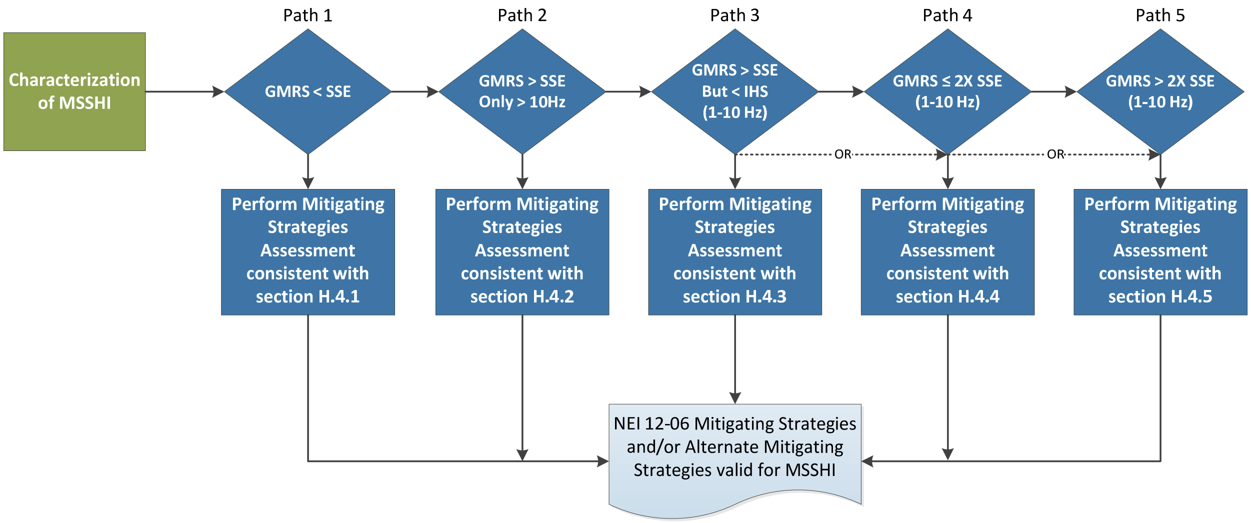

Figure H.2: Mitigating Strategies Assessment Process for the MSSHI

H.4 EVALUATION OF MITIGATING STRATEGIES FOR THE MSSHI

The MSA is performed in order to determine if the FLEX strategies developed and implemented per this guidance can be implemented considering the impacts of the MSSHI.

If the SSE spectrum bounds the GMRS at frequencies 1 Hz and greater, licensees should follow the process described in Section H.4.1 (Path 1 in Figure H.2) to document completion of the MSA demonstrating that the FLEX strategies can still be implemented as designed since the impacts of the MSSHI are bounded by the hazard for which the mitigating strategies were designed. As described in H.4.1, this process also includes licensees with de minimis GMRS exceedance above SSE.

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[1] Some plants have used the term "Design Basis Earthquake" or DBE, which is synonymous to SSE.

In the event that the GMRS is not bounded by the SSE, the purpose of the MSA is to determine if the FLEX strategies can be implemented as designed in view of the impacts of the MSSHI, or if the FLEX strategies can be modified to address the identified impacts from the MSSHI. For some scenarios it may be more effective (e.g., require less resources, simpler to implement, more reliable, result in overall improvement in protection, etc.) to address the impacts of the MSSHI through the development of an AMS as opposed to modifying the FLEX strategies. Sections H.4.2 through H.4.5 of this appendix provide different approaches for performance of the MSA in order to make this determination.

The MSA evaluates the plant equipment, FLEX equipment, operator actions, plant and site conditions, and procedures required to successfully implement the FLEX strategies so that a site may cope indefinitely with the effects of the MSSHI. Only a single success path is required for the safety functions identified in Tables 3-1 and 3-2. Equipment required to support an alternative means to accomplish a function is not required to be included in the MSA.

1. Section 3.2.2.17 requires primary and alternate connection points for portable equipment. Only one connection point needs to be included, provided the required function can still be accomplished. Justification should be provided for any cases where the primary connection point is not selected.
2. Limiting instrumentation to one indication per key parameter is acceptable, provided the required function can still be accomplished.
3. Plants may have identified additional resources that may be beneficial, but are not required (e.g. multiple water sources available for CST makeup). Only the minimum set of sources to perform the required function needs to be considered.

For each of the paths identified in H.4.1 through H.4.5, the MSA should be documented per Section H.6 of this appendix.

H.4.1 PATH 1: GMRS < SSE

If the GMRS described in Section H.2 is bounded by the SSE spectrum at frequencies 1 Hz and greater, then additional evaluation is unnecessary. For the purposes of determining if the GMRS is bounded by the SSE spectrum, de minimis GMRS exceedance above SSE accepted in the site-specific NTTF 2.1 final determination letter can be considered to meet the Path 1 screening assessment [4]. The basis of accepting these small exceedances is that they are considered to be inconsequential; also similar narrow band exceedances have been deemed acceptable in industry standards such as IEEE Std. 344-1987. For plants meeting these criteria, the FLEX strategies can be implemented as designed and no further seismic evaluations are necessary.

H.4.2 PATH 2: GMRS < SSE WITH HIGH FREQUENCY EXCEEDANCES

Introduction:

For plants where the GMRS spectrum above 10 Hz exceeds the SSE spectrum, licensees can demonstrate adequacy of the FLEX strategies with respect to the MSSHI by performing an MSA that consists of an evaluation of high frequency (HF) sensitive plant equipment required for strategy implementation.

If the GMRS described in Section H.2 is less than the SSE in the 1 to 10 Hz range consistent with Section 3.2 of EPRI 1025287 [3], but is not bounded at frequencies greater than 10 Hz, an MSA should be performed as shown in Figure H.2 for Path 2. For the purposes of determining if the GMRS is bounded by the SSE spectrum in the 1 to 10 Hz range, de minimis GMRS exceedance above SSE accepted in the site-specific NTTF 2.1 final determination letter can be considered to meet the Path 2 screening assessment [4].

Basis:

SSE exceedances in the high frequency range (i.e.,>10 Hz) can be evaluated by performing an MSA to show that equipment potentially sensitive to high frequency vibration will not prevent performance of the FLEX strategies. The methods for performing the high frequency evaluation are defined in Sections 3 and 4 of EPRI 3002004396 [5]. The acceptance criteria defined in Section H.5 should be used in these evaluations. The minimal high frequency exceedances defined in Sections 3.1.1 and 3.1.2 of EPRI 3002004396 are considered inconsequential; they do not cause a high frequency concern and do not require additional evaluations.

Background and Discussion:

Section 4 of EPRI 3002004396 [5] describes an HF evaluation process focusing on contact control devices subject to intermittent states (e.g., relay chatter) in seal-in and lockout circuits. For the MSA HF evaluation, the acceptance criteria from Section H.5 can be used and the scope of circuits to be reviewed include plant equipment credited for the Phase 1 response as well as permanently installed Phase 2 SSCs that have the capability to begin operation without operator manual actions.

The MSA HF evaluation scope is focused on seal-in and lockout circuits in the following systems and equipment.

- Devices whose chatter could cause malfunction of a reactor SCRAM.[2]
- Devices in seal-in or lockout circuits whose chatter could cause a reactor coolant system (RCS) leakage pathway that was not considered in the FLEX strategies. Examples include the automatic depressurization system (ADS) actuation relays in boiling-water reactors (BWRs) and relays that could actuate pressurizer power-operated relief valves (PORVs).
- Relays and contactors that may lead to circuit seal-ins or lockouts that could impede the Phase 1 FLEX capabilities, including buses fed by station batteries through inverters.
- Relays and contactors that may lead to circuit seal-ins or lockouts that could impede FLEX capabilities for mitigation of seismic events in permanently installed Phase 2 SSCs that have the capability to begin operation without operator manual actions.

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[2] A SCRAM is a manually-triggered or automatically-triggered rapid insertion of all control rods into the reactor, causing emergency shutdown.

H.4.3 PATH 3: GMRS > SSE BUT < IHS

Introduction:

If the high-confidence-of-low-probability-of-failure (HCLPF) plant capacity spectrum developed from the evaluations for Individual Plant Examination of External Event (IPEEE) envelops the GMRS between 1 and 10 Hz with the exception of small narrow band exceedances that meet the criteria of Section 3.2.1.2 of EPRI 1025287 [3], an AMS may be used based upon the IPEEE Path 3. IPEEE safe shutdown paths would be used to demonstrate robustness to the MSSHI of SSCs relied upon for the AMS. Alternatively, licensees may elect to perform an MSA of the impacts of MSSHI on FLEX strategies as shown in Figure H.2 for Path 4 or perform an MSA for Path 5 shown in Figure H.2.

An IPEEE-based MSA relies on the comprehensive seismic evaluation of plant equipment to demonstrate robustness of SSCs to the MSSHI. Licensees that are eligible to use this path rely on the previous seismic evaluations that were conducted under the IPEEE effort and accepted by the NRC per Enclosure 2 of their May 9, 2014 letter [6] or in a subsequent screening determination that was issued through the letter dated October 27, 2015 [4], provided that the IPEEE HCLPF spectrum (IHS) envelops the GMRS between 1 and 10 Hz, with the exception of small narrow band exceedances that meet the criteria in EPRI 1025287 [3]. For those eligible plants, the mitigating strategy may be based upon the IPEEE, consistent with Path 3 of Figure H.2. IPEEE safe-shutdown paths would be used to demonstrate robustness to the MSSHI of SSCs relied upon for these strategies. Alternatively, licensees may elect to perform an MSA of the impacts of MSSHI on mitigating strategies consistent with Path 4 of Figure H.2 or perform an SPRA-informed MSA consistent with Path 5 of Figure H.2. The development of the IHS is described in Section 3.3.2 of EPRI 1025287 [3].

IPEEEs relied on the results of an SPRA, an EPRI seismic margins assessment (SMA) methodology, or an NRC SMA methodology to demonstrate the capability to bring the plant to a safe shutdown condition following a review level earthquake (RLE) as described in NUREG-1407 [7]. These seismic evaluation approaches evaluated multiple redundant safe shutdown success paths. The safe shutdown success paths provide independent means of achieving a safe shutdown condition following a severe seismic event (e.g., core cooling by heat removal from the steam generators and core cooling by RCS ‘feed and bleed’).

To provide a complete MSA seismic evaluation, the IPEEE evaluation is supplemented by reviews of spent fuel pool cooling functions and high frequency exceedances (as applicable).

Basis:

Seismic evaluations performed under IPEEE included SSCs in multiple redundant safe shutdown success paths. Therefore, based on the results of the IPEEE, safe shutdown of the plant following a seismic event can be accomplished, and consequences can be mitigated, for a seismic event up to the plant capacity level (i.e., the IHS) for which the SSCs in the IPEEE were evaluated.

In addition, seismic evaluations for spent fuel pool cooling should be performed using the MSSHI to demonstrate that spent fuel would remain cooled following a seismic event, and a review of HF sensitive components should be performed, as needed.

Background and Discussion:

IPEEE Evaluations

The IPEEEs were completed by plants in the 1990s under NRC Generic Letter (GL) 88-20 Supplements 4 [8] and 5 [9] in accordance with the guidance of NUREG-1407 [7]. Acceptable approaches to perform IPEEE included the NRC seismic margin assessment (SMA) method, the EPRI SMA method, or an SPRA. For each approach, a seismic equipment list (SEL) was developed that included multiple redundant safe shutdown success paths and/or accident sequences. The evaluation of robustness to the MSSHI of the SSCs in these redundant safe shutdown success paths demonstrates the capability to maintain or restore core cooling and containment capabilities for a beyond-design-basis seismic event up to the level of the IHS, which envelopes the GMRS in the 1 to 10 Hz range.

The IPEEEs were generally performed using input motions based on the following:

a. Median-centered response spectrum using the NUREG/CR-0098 [10] shape, anchored to 0.3g peak ground acceleration (PGA).
b. For SPRAs, plants generally used the mean Uniform Hazard Response Spectra and hazard curves developed by Lawrence Livermore National Laboratory (LLNL) in NUREG-1488 [11] and/or EPRI in EPRI NP-6395-D [12].
c. In some cases, past SPRAs were submitted for IPEEE closure that used input motions and hazard curves that preceded the LLNL and EPRI hazard curves of NUREG-1488 [11] and EPRI NP-6395-D [12] respectively.

Consistent with the input spectrum shape used in an IPEEE, an IHS can be developed, as described in EPRI 1025287 [3].

Indefinite Coping

For those plants for which the IHS has been already determined to be acceptable and used the EPRI SMA approach based on EPRI NP-6041-SL Rev. 1 [15], the SEL for evaluation of safe shutdown success paths was comprised of those SSCs required to bring the plant to a stable condition (either hot or cold shutdown) and maintain that condition for at least 72 hours. Therefore, for those plants with an IPEEE based on the SMA described in EPRI 1025287 [6] approach, the IPEEE results must be evaluated for limitations that are based on the 72 hour coping duration. Plants that performed a seismic PRA or the NRC margin method for IPEEE may have limitations based on coping durations of less than 72 hours that also need to be further evaluated for meeting the intent of mitigating strategies to cope indefinitely. Generally, the conclusions of the SMAs and SPRAs are not sensitive to coping duration. However, certain consumable items, such as water and fuel oil inventories, may have been evaluated based on a limited onsite supply. The ability to continue coping would require re-supply of consumables. This issue is addressed in Sections 3.3 and 12. A plant-specific evaluation should be performed to conclude that SSCs that limit the EPRI SMA-based IPEEE coping duration to 72 hours are available for an indefinite period following a beyond design-basis seismic event at the reevaluated seismic hazard to support continued maintenance of the safe shutdown condition.

IPEEE Upgrade to Full Scope

As noted above, these plants have an IHS that completely envelops the GMRS between the frequency range of 1 and 10 Hz, with the exception of small narrow band exceedances that meet EPRI 1025287 [3] criteria. To apply this approach, licensees conducted a full scope IPEEE or, if a licensee conducted a plant focused- scope IPEEE, the licensee brought the focused-scope IPEEE assessment to be consistent with a full-scope IPEEE assessment as defined in GL 88-20 Supplements 4 [8] and 5 [9] and NUREG-1407 [7] in accordance with the guidance in EPRI 1025287 [3]. If additional evaluations (e.g., full-scope relay review) were identified to bring the IPEEE to full scope, but are not yet completed, then the successful demonstration must be completed to use this path.

Spent Fuel Pool Cooling Evaluation

Licensees following this path need to ensure the credited SFP cooling capability is maintained. Equipment (SFP makeup capability, SFP level instrumentation) needed to accomplish the spent fuel cooling function should be evaluated using the criteria in H.5 to demonstrate robustness to the MSSHI. For developing in-structure response spectrum (ISRS) corresponding to the GMRS, the SSE-based ISRS are developed by scaling the highest ratio of GMRS/SSE in the 1 to 10 Hz range for these evaluations. This process is typically conservative because it applies the highest GMRS-to-SSE ratio over the entire 1 Hz to 10 Hz frequency range. A high frequency evaluation of the SFP cooling key safety functions is not warranted since operators would have a significant amount of time to restore SFP cooling, as documented in the times for initiation of SFP makeup contained within the FLEX strategies.

High Frequency Evaluation:

Licensees following this path that also have high frequency exceedances (GMRS > IHS above 10 Hz) should perform a high frequency evaluation of relays in the IPEEE scope consistent with the criteria in Sections 3 and 4 of EPRI 3002004396 [5], using the acceptance criteria in H.5.

Availability of FLEX Equipment:

With the exception of SFP cooling, the AMS described in H.4.3 does not rely upon availability of FLEX equipment. In these cases where the AMS does not rely upon the availability of FLEX equipment, availability of FLEX equipment should still be treated in the MSA as a means of additional defense in depth.

On-site FLEX equipment is available for deployment to support the maintenance of core cooling, containment, and spent fuel cooling functions. In order to provide additional potential mitigating capability, portable FLEX equipment not being used for the AMS should be stored in accordance with Section 5.3.1. No strategies need to be preplanned for the use of this equipment.

Additionally, the licensee will maintain the capability to obtain additional portable FLEX equipment from offsite sources. No strategies need to be preplanned for the use of the offsite equipment.

H.4.4 PATH 4: GMRS ≤ 2X SSE

Licensees who determine that a plant GMRS described in Section H.2 has spectral ordinates greater than the SSE but no more than 2 times the SSE anywhere in the 1 to 10 Hz frequency range may use Path 4, as described below to perform an MSA of the impacts of the MSSHI on FLEX strategies. These licensees may also elect to follow Path 5 of Section H.4.5 of this Appendix.

Introduction:

For licensees with low to moderate GMRS (up to 2 times the SSE in the 1 to 10 Hz frequency range), selected plant equipment relied upon in the FLEX strategies was previously evaluated up to 2 times the SSE under the Expedited Seismic Evaluation Process (ESEP), as described in EPRI 3002000704 [15]. The scope of SSCs necessary to be evaluated under the MSA needs to be identified and methods are provided to demonstrate adequate seismic ruggedness. These methods include use of qualitative criteria based on previous experience to show adequate seismic ruggedness as well as a more quantitative approach based on the criteria described in Section H.5 to demonstrate SSCs are seismically robust up to the GMRS earthquake level.

Basis:

Equipment used in support of the FLEX strategies has been evaluated to demonstrate adequacy following the guidance in Section 5. Previous seismic evaluations should be credited to the extent that they apply. This includes the design basis evaluations for the plant, and the ESEP evaluations for the FLEX strategies in accordance with EPRI 3002000704 [15]. The ESEP evaluations remain applicable for this MSA since these evaluations directly addressed the most critical 1 Hz to 10 Hz part of the new seismic hazard using seismic responses from the scaling of the design basis analyses. In addition, separate evaluations should be performed to address high frequency exceedances under the HF assessment process defined in EPRI 3002004396 [5]. These high frequency evaluations should be performed as applicable for the equipment supporting the FLEX strategies. The new evaluations should use the MSA seismic performance goal defined in Section H.5. Licensees following this path may also have HF GMRS exceedances above the SSE at frequencies above 10 Hz. The specific assessment of the high frequency exceedance for the Path 4 plants is identical to the procedure described in Section H.4.2 and should be used here also.

Special Case for GMRS ≤ 1.4X SSE

A special case applies within Path 4 for licensees whose GMRS is no more than 1.4 times the SSE. The MSA seismic performance goal criteria described in Section H.5 consists of demonstrating that each SSC has no more than a 10% probability of unacceptable performance given the GMRS level earthquake for the site. As shown in Table H.1, this 10% probability of unacceptable performance is a factor of approximately 1.4 higher than the 1% probability of unacceptable performance (i.e. the HCLPF level). Since the SSE for the plant would typically define the lower bound of the HCLPF level for an individual SSC, any SSC evaluated to the SSE would also meet the MSA seismic performance goal. This is consistent with the expectations on page 2-55 of EPRI NP-6041 SL Revision 1 [13] which notes that it is conservative to accept the SSE as the CDFM Seismic Margin Earthquake level. Therefore, licensees whose GMRS is no more than 1.4 times the SSE between 1 & 10 Hz do not need to provide additional seismic robustness evaluations for plant equipment. These licensees only need to perform the following evaluations:

a. a high frequency evaluation as described in Section H.4.2
b. an assessment the of the FLEX storage building if the provisions in section 5.3.1 paragraph 1.b was applied, and
c. the haul path assessment as described in Step 3.

If a licensee can demonstrate that the variabilities should be higher than those used in the minimum bounding case of Table H.1, then a factor higher than 1.4 may be used, with appropriate justification.

Background and Discussion:

Plant equipment relied on for FLEX strategies have previously been evaluated as seismically robust to the SSE levels. The MSA of Path 4 SSCs is conducted as described below and illustrated in Figure H.3:

1. *Scope of Plant Equipment for the MSA* – The scope of SSCs is determined following the guidance in the ESEP [15], and adding the SSCs excluded from the ESEP. The SSCs excluded from the ESEP that need to be added and evaluated are the following:
    - Structures (e.g., containment, reactor building, control building, auxiliary building).
    - Piping, cabling, conduit, and their supports
    - Manual valves, check valves, and rupture disks
    - Power operated valves not required to change state
    - Nuclear Steam Supply System (NSSS) components
    - FLEX storage buildings
    - FLEX haul paths and operator pathways

    In addition, SSC failure modes not addressed under the ESEP need to be added and evaluated. These failure modes are the seismic interactions that could potentially affect the FLEX strategies (note that block walls near plant equipment credited for FLEX strategies and differential displacement of piping attached to tanks were evaluated under the ESEP).

2. *Step 1: ESEP Review* – The ESEP provided an evaluation that demonstrated seismic adequacy for all components in a single success path for core cooling, RCS makeup, and containment function strategies for a scaled SSE spectrum that bounded the GMRS from the re-evaluated seismic hazard (1 to 10 Hz) or the GMRS was directly used. The ESEP was an interim evaluation and included a review for all potential failure modes with the one exception of the full review of all potential seismic interactions. The ESEP included the reviews of seismic interactions associated with block walls in the vicinity of the ESEP equipment and differential displacement type interactions for tanks. As such, any additional

seismic interaction failure modes affecting the ESEP equipment would need to be considered as part of the MSA. Outside of these additional seismic interaction reviews, no further work is required to demonstrate robustness to withstand the new seismic hazard for those SSCs that were within the scope of the ESEP.

3. *Step 2: Qualitative Assessment Based on Seismic Experience* – The qualitative assessment of SSCs not included in the ESEP is accomplished using (1) a qualitative screening of "inherently rugged" SSCs and (2) evaluation of SSCs to determine if they are "sufficiently rugged."

   Certain classes of equipment that have high seismic capacities need little or no further actions to demonstrate their capability to withstand the new seismic hazard.

   Certain SSCs are inherently rugged and the long-standing practice has been to not include the seismic failure of such SSCs into SPRA logic models. By definition, these inherently rugged components have demonstrated high seismic capacity to withstand the seismic hazard and require no further action to demonstrate robustness. The recent EPRI SPRA Implementation Guide (SPRAIG) [25] identifies several such inherently rugged components, including:

   - Strainers and small line mounted tanks
   - Welded and bolted piping
   - Manual valves, check valves, and rupture disks
   - Power operated valves (MOVs and AOVs) not required to change state

   In addition to the inherently rugged SSCs, there are additional classes of SSCs that have high seismic capacities and can withstand the relatively moderate GMRS levels for Path 4, which are less than twice the SSE levels in the critical 1 to 10 Hz range. These high capacity components have demonstrated seismic adequacy on an equipment class basis to withstand the seismic hazard for all Path 4 plants with minimal supplemental evaluations required. This group of equipment is determined to be "sufficiently rugged" for purposes of Path 4. The EPRI NP-6041 [13] seismic margin report serves as a good reference to demonstrate robustness for several SSCs. The 5% damped peak spectral acceleration values for all Path 4 plants are below 0.8 g. As such, the first column of Table 2-3 establishes a $HCLPF_{1\%}$ capacity level for nuclear structures.

   The following structures have established adequate seismic capacity to withstand the GMRS for Path 4 plants based on the EPRI NP-6041 screening criteria and do not require additional evaluations to demonstrate robustness:

   - Concrete containment and containment internal structures
   - Shear walls, footings and containment shield walls
   - Diaphragms (floors)
   - Category 1 concrete frame structures
   - Category 1 steel frame structures

   In addition, two classes of high capacity equipment and systems have also been established in EPRI NP-6041 to have adequate seismic capacities relative to the

GMRS for Path 4 plants and do not require additional evaluations to demonstrate robustness:

- Raceways (Cable Trays and Conduit)
- Nuclear steam supply system (NSSS) components (piping and vessels)

Cable trays and conduits do not have any caveats and restrictions associated with the use of the 0.8g spectral acceleration column of Table 2-4. In addition, since raceway earthquake experience data exists at elevations higher than 40 feet above grade, the caution on use of Table 2-4 from EPRI NP-6041 does not apply to both cable trays and conduit. This use of the 0.8g seismic capacity for raceways at all elevations in the plant is also consistent with Section 8.0 of the SQUG GIP Revision 3A which was used in the resolution of USI A-46.

NSSS piping and supports are typically mounted low in the structure and are within 40 feet above grade. The NSSS piping and vessels have been shown to have high seismic capacities in past SPRAs. In light of the fact that the EPRI NP-6041 Table 2-4 0.8g peak spectral acceleration represents a HCLPF threshold and that the MSA seismic robustness criteria in H.5 is a $C_{10\%}$ level of adequacy, the NSSS piping and vessels are judged not to require any further effort to demonstrate robustness. This conclusion is supported by the NRC study on transition break size. The NRC reviewed the seismic risks associated with both direct NSSS piping seismic failures and also indirect seismic failures (due to NSSS vessel and component seismic failures) and concluded that the probability of seismically induced failure to be less than 10^{-5} per year.

Step 3: Assessment Based on the Criteria Defined in Section H.5 – SSCs and seismic interactions that were not included within the ESEP review (Step 1) and cannot be justified to be sufficiently rugged with respect to the GMRS (Step 2) should be evaluated to demonstrate adequate seismic ruggedness. Section H.5 describes the methodology for demonstrating the robustness of equipment used in the FLEX strategies. The equipment and interactions to be considered are:

- FLEX Equipment Storage Building and Non-Seismic Category 1 Structures that could impact FLEX implementation
- Operator Pathways – interaction pathway review, use Section H.5 methods if calculation is required
- Tie down of FLEX portable equipment that are required to be restrained during the earthquake
- Seismic interactions that could potentially affect the FLEX strategies and were not previously reviewed as part of the ESEP program should also be addressed (e.g. flooding from non-seismically robust tanks and interactions to distributed systems associated with the ESEP equipment list). This assessment could be conducted based on a sampling walkdown review to verify that credible seismic interactions are not present.
- Haul Path, including liquefaction, slope stability, and seismic interactions. Options for demonstrating an acceptably low probability of haul path failure include:

- demonstrating that a $C_{10\%}$ capacity of the haul path exceeds the GMRS, or
- justifying that a particular failure mode (such as liquefaction induced failures at a hard rock site) would not be credible, or
- crediting on-site capabilities for debris removal to reestablish a haul path following the beyond design basis earthquake.

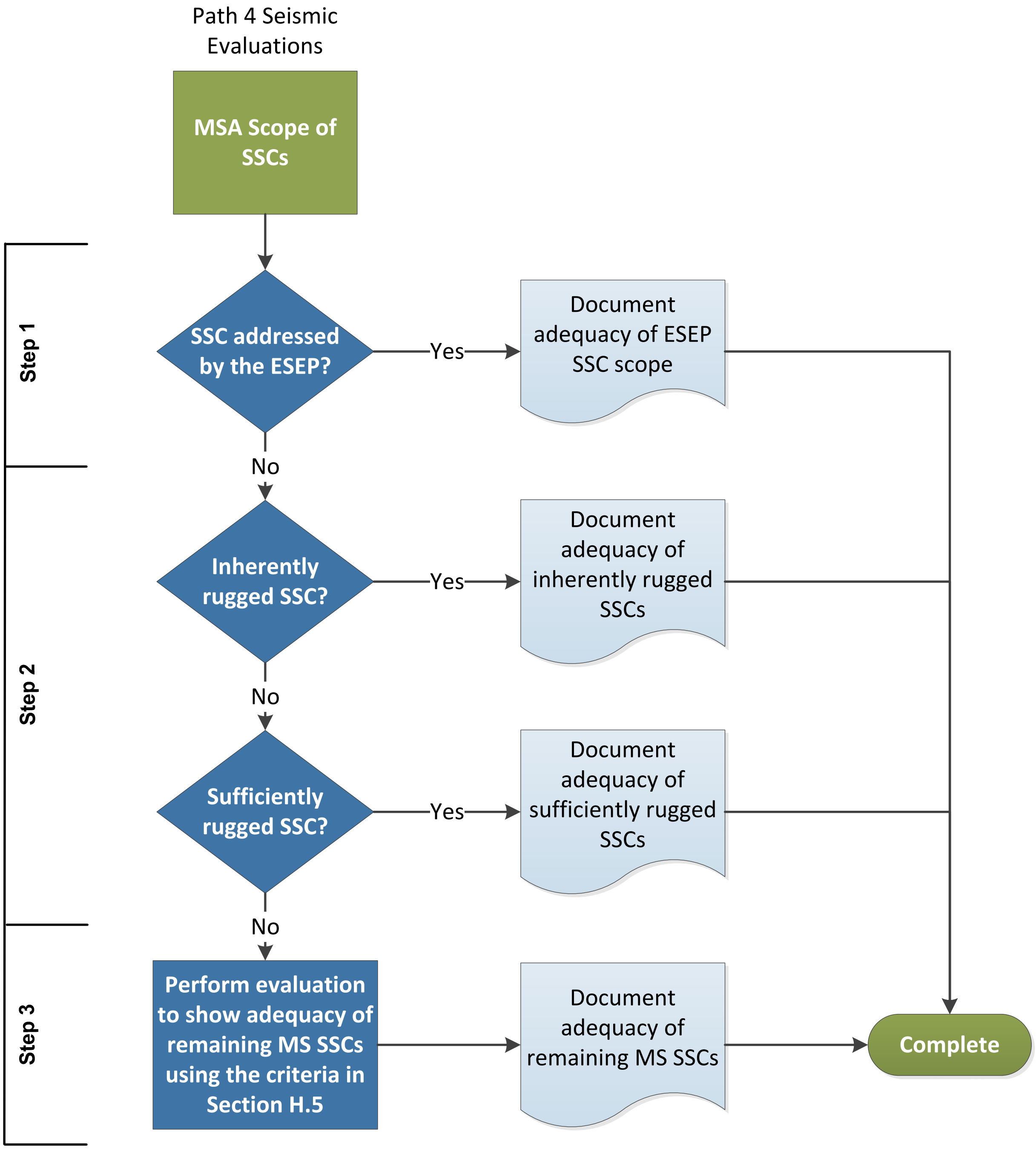

Figure H.3: Evaluation of Path 4 SSCs with the MSA

Restrictions:

The restrictions and caveats that apply in using this path are as follows.

- GMRS spectral ordinates must be less than or equal to 2 times the SSE at all frequencies in the 1 to 10 Hz range.

Other Considerations:

High Frequency

Licensees with GMRS exceedances of the SSE above 10 Hz need to perform an HF evaluation of relays in accordance with the methodology described in Section H.4.2.

Spent Fuel Pool Cooling

Licensees following this path need to ensure the SFP cooling FLEX strategies are maintained. Equipment (SFP makeup capability, SFP level instrumentation) needed to accomplish the spent fuel cooling strategies should be evaluated for seismic adequacy to the GMRS. A high frequency evaluation of the SFP cooling key safety functions is not warranted since operators would have a significant amount of time to restore SFP cooling, as documented in the FLEX strategies.

H.4.5 PATH 5: GMRS > 2X SSE

Licensees who determine that a plant GMRS described in Section H.2 has spectral ordinates greater than 2 times the SSE anywhere in the 1 to 10 Hz frequency range may use their SPRA results; or elements based on the SPRA.

An approach to demonstrate the capability to maintain or restore core cooling and containment capabilities can be developed that involves evaluation of the risk contribution from the ELAP / LUHS sequences in a SPRA. Alternatively, the mitigating strategy SSCs (i.e., SSCs credited in the SPRA for plant response in the ELAP / LUHS sequences) that the SPRA shows are important to ELAP/LUHS risk can be shown to have a $C_{10\%}$ capacity (per the performance criteria in H.5) ≥ GMRS, using ISRS that are based on the GMRS.

Detailed guidance using the above concepts and other potential variations that define mitigating strategies based on the SPRA results is under development and expected to be available to support MSAs for Path 5.

H.5 SEISMIC EVALUATION CRITERIA ($C_{10\%}$)

The definition for robustness for SSCs relied upon in the FLEX strategies consists of demonstrating that these SSCs have adequate capacity to withstand the GMRS level of seismic hazard at the site. The FLEX strategies serve as a defense in depth to the existing safety systems and, as such, a 90% probability of success criteria is judged sufficient to verify adequate capacity for this beyond seismic design basis review. Precedence for establishing this 90% probability of success criteria exists within a national standard for nuclear SSCs and within a seismic guideline for commercial structures as described below.

The use of a 90% probability of success is equivalent to a 10% probability of unacceptable performance. This use of the 10% probability of unacceptable performance has been used in the past as a criteria for demonstrating seismic adequacy for beyond design basis seismic performance reviews in standards such as ASCE 43-05 [17] and in commercial criteria such as ATC-63 [18].

ASCE/SEI 43-05 [17] defines a 10% probability of unacceptable performance ($C_{10\%}$) which is reviewed against the beyond design-basis seismic event (150% of the DBE ground motion for the ASCE/SEI 43-05 case). ASCE 43-05 takes advantage of known seismic margin in the seismic designs (e.g. ductility, negligible effects of small displacements, conservative damping, etc.) to justify that the overall risks of unacceptable performance are acceptably low when using the $C_{10\%}$ evaluation criteria.

This same 10% probability of unacceptable performance was used in a recent Applied Technology Council (ATC) project, ATC-63 [18], which defined the acceptable low probability of collapse levels for structural evaluations to be the $C_{10\%}$ value. The ATC-63 project stated "*acceptably low probability of collapse is interpreted to be less than a 10% probability of collapse under the [maximum credible earthquake] MCE ground motions*" as shown in Structural Engineers Association of California (SEAOC) 2007 Convention Proceedings [19]. The MCE is the equivalent of the beyond design-basis seismic event for normal building code applications such as the ATC-63. The existing plant safety systems provide the primary seismic response strategy for the plant and the FLEX strategies perform a defense-in-depth role in the case of an extreme seismic event. The demonstration of seismic adequacy to the $C_{10\%}$ performance criteria for the FLEX strategies represents additional plant seismic safety and is judged to be an adequate performance level of seismic ruggedness.

Performance Target for Mitigating Strategy

As stated above, the FLEX strategies represent a defense-in-depth for the normal plant safety systems in the event of a beyond design basis seismic event. The associated performance target for the FLEX strategies should not be set at the same level as that of the primary safety systems, which have generally been aligned with a 1E-5 performance target. In order to investigate the impact of the use of the $C_{10\%}$ capacity criteria described above for FLEX strategies, a fleet risk assessment was conducted. To perform this assessment, point estimates of the Annual Frequency of Unacceptable Performance (AFUP) have been developed using an approach similar to that developed by the NRC to address the plant seismic risk associated with the new seismic hazards developed in 2010 as part of the GI 199 program [20]. The FLEX strategies AFUP estimates were developed based on:

- the most recent seismic hazards for the US nuclear plants submitted to the NRC,
- an assumption that the plant level $C_{10\%}$ capacity can be estimated to be equivalent to the minimum SSC $C_{10\%}$ capacity (by definition each SSC $C_{10\%}$ capacity will be greater than or equal to the GMRS),
- a plant fragility function using this $C_{10\%}$ capacity and a generic Beta value using the Hybrid fragility approach, and
- a convolution of the seismic hazard with the plant level fragility to calculate an estimated AFUP.

In order to ensure that the full range of potential AFUP values is reviewed, the following sensitivity studies were conducted:

- Composited Beta (β_C) values were varied between 0.35 and 0.45 in conformance to the values documented in the EPRI SPID
- The AFUP were computed seismic hazard estimates from six different structural frequencies (1, 2.5, 5, 10, 25 and 100 Hz)

The results from these risk studies are plotted in Figure H.4. Each curve represents the cumulative AFUP distribution for all US plants using one of the sensitivity parameters (β_C and structural frequency). In all cases, the highest results are lower than 5E-5 AFUP. Given these moderate AFUP estimates, the $C_{10\%}$ capacity is judged to be an acceptable seismic performance goal for demonstrating robustness for the FLEX strategies. The defense-in-depth provided by the FLEX strategies reduces the existing seismic risk associated with the plant normal safety systems.

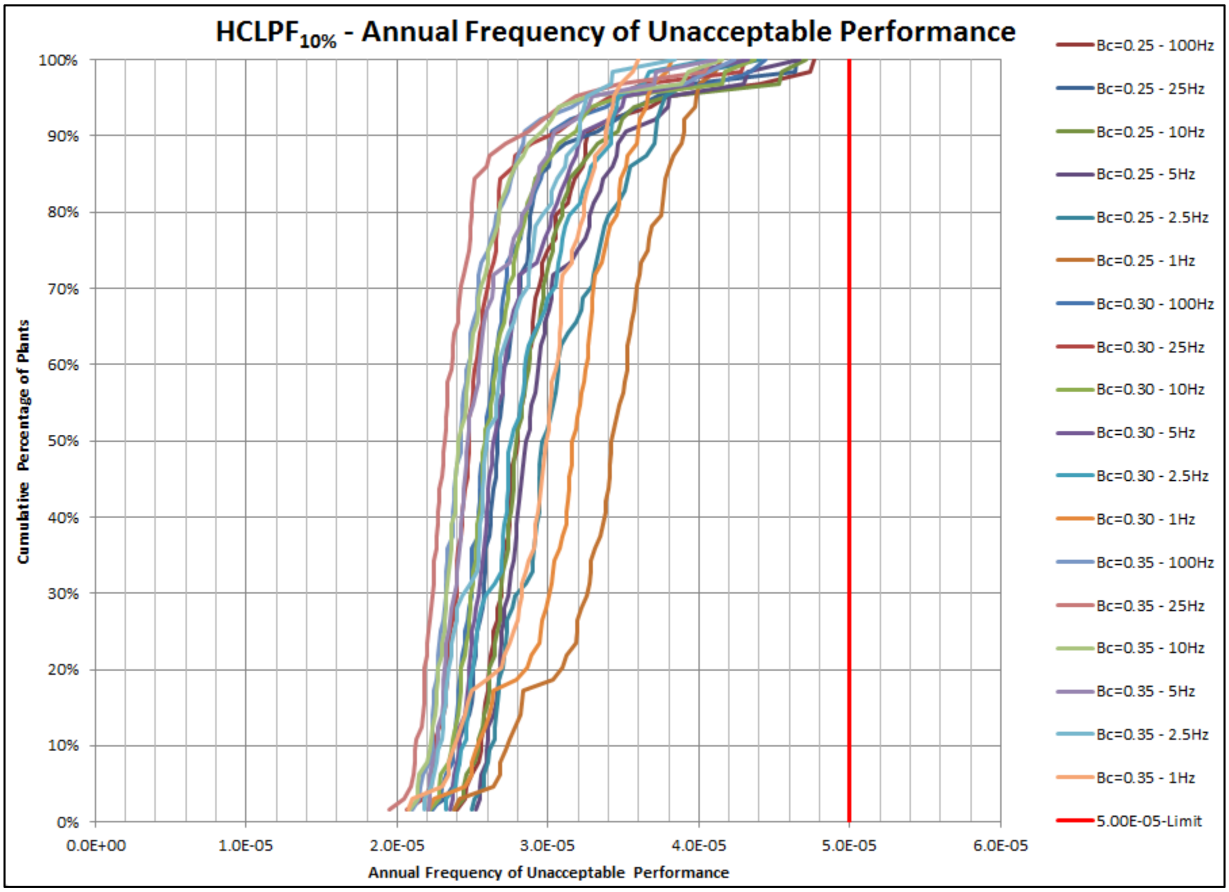

Figure H.4: US Nuclear Plant Fleet Mitigating Strategy Risk Cumulative Distribution

<u>Discussion on $C_{10\%}$ calculations</u>

The process for calculating the $C_{10\%}$ values are defined in this section. Table H.1 provides recommended values for β_C, β_R, β_U, and the ratio of the median capacity $C_{50\%}$ to the $C_{1\%}$ capacity taken from EPRI 1025287 [6]. The recommended β_C values are based on Dr. Robert Kennedy's recommendations [21] and on average are biased slightly conservative (i.e., slightly low β_C on average). Because random variability β_R is primarily due to ground motion variability, a constant β_R value of 0.24 is recommended regardless of the SSC being considered. In addition to the values provided in EPRI 1025287, values are also included associated with a β_C of 0.3. This lower bound β_C value could represent the variability associated with failure modes with the least difference between the median and HCLPF values. Past fragility and HCLPF assessments have shown that some brittle failure modes and some block wall failure modes could have values that might approach this 0.3 β_C level. The recommended uncertainty β_U values are estimated from the recommended composite β_C and β_R values. The β values for Table H.1 apply to fragilities tied to ground motion parameters (e.g., PGA or Peak Spectral Acceleration at 5 Hz). The ratios of the 10% failure probability capacity ($C_{10\%}$ to the $C_{1\%}$ capacity) have been calculated and are shown in the last column of Table H.1. The methodology for demonstrating the adequate seismic ruggedness for the FLEX strategies would follow the approach for an SMA wherein a defined capacity is shown to exceed the defined demand. In the case of an SMA, the demand for the assessment is referred to as the Review Level Earthquake (RLE). The following steps would be used for SSCs relied upon in the FLEX strategies for the $C_{10\%}$ review:

- The GMRS will be the RLE for the reevaluated seismic hazard review of the FLEX strategies
- The seismic capacity for demonstrating robustness will be the $C_{10\%}$ value. The $C_{10\%}$ can be calculated by:
  - Calculate the $C_{1\%}$ capacity using the methods documented in past SPRA and seismic margin documentation and as summarized in EPRI 1025287 [6].
  - Multiply the $C_{1\%}$ capacity by the $C_{10\%}/C_{1\%}$ ratio from Table 1 based on the type of SSC being evaluated
- Verify that the $C_{10\%}$ capacity exceeds the RLE demand

Table H.1: Recommended β_C, β_R, β_U, and $C_{50\%}/C_{1\%}$ Values to Use in Hybrid Method for Various Types of SSCs

Type SSC	Composite β_C	Random β_R	Uncertainty β_U	$C_{50\%}/C_{1\%}$	$C_{10\%}/C_{1\%}$
Structures & Major Passive Mechanical Components Mounted on Ground or at Low Elevation Within Structures	0.35	0.24	0.26	2.26	1.44
Active Components Mounted at High Elevation in Structures	0.45	0.24	0.38	2.85	1.60
Other SSCs	0.40	0.24	0.32	2.54	1.52
Realistic Lower Bound Case[3]	0.30	0.24	0.18	2.00	1.36

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[3] These lower bound values can be used for relays, block walls, and SSCs with brittle failure modes if more realistic beta values cannot be estimated.

In addition, a sensitivity study was conducted to assess an even lower composite uncertainty case, with a β_C of 0.25. For this sensitivity study case, the $\mathbf{C_{50\%}/C}_{1\%}$ ratio equates to a 1.22 value. The purpose of this sensitivity study was to verify that the conclusions associates with achieving a 5E-5 AFUP were not sensitive to the lower bound β_C value of 0.3. As shown in Figure H.4 the AFUP for the β_C of 0.25 case is still lower than 5E-5 per year.

H.6 DOCUMENTATION

Document the characterization of the MSSHI for the site.

Document whether the GMRS is bounded or not bounded by the SSE and describe the nature of any element not bounded.

Document the results of the process in Section H.4 and the basis for selecting the mitigating strategy.

6.1 Path 1: Document the evaluation that demonstrates existing FLEX strategies are acceptable without modification for the MSSHI Path 1.

- Document that the FLEX strategies can be implemented for the MSSHI
- Description of the GMRS to SSE comparison

6.2 Paths 2 and 4: Document the evaluation that demonstrates that modifications enable FLEX strategies to be implemented based on the impacts of the MSSHI. The following items should be included:

- Discussion of the GMRS to SSE comparison
- Identification of the MSSHI impacts to the FLEX strategies, as appropriate
- A revised sequence of events demonstrating the necessity of revised FLEX actions, as appropriate
- Description and justification of the modifications (equipment, procedures, etc.) to address the revised FLEX actions, as appropriate
- Description of approach to address additional considerations for Path 4 (e.g. high frequency, spent fuel cooling)
- Validation documents in accordance with Appendix E, as appropriate

6.3 Path 3: Document the evaluation that concludes that the selected strategy will mitigate the MSSHI. The following items should be included:

- Description of comparison of the GMRS to IHS
- Description of plant-specific IPEEE and adequacy from March 2014 submittal
- Description of the AMS and how it provides evaluation of redundant paths to plant safety
- Description of approach to address items (including any modifications) outside scope of IPEEE (e.g. spent fuel pool cooling)
- Description of any limitations and how they are accommodated

- Description of evaluation of IPEEE to full scope
- Description of availability of FLEX equipment
- Validation documents in accordance with Appendix E

The documentation identified above should be included in and be of the same level of detail as that included in the Program Document.

H.7 REFERENCES (Note: references to be confirmed when the document is complete)

1. U.S. NRC (Leeds, E & Johnson, M.), "*Request for Information Pursuant to Title 10 of the Code of Federal Regulations 50.54(f) Regarding Recommendations 2.1, 2.3, and 9.3 of the Near-Term Task Force Review of Insights from the Fukushima Dai-Ichi Accident*", Letter to All Power Reactor Licensees et al., Washington D.C., March 12, 2012.
2. U.S. NRC, "*Issuance of Order to Modify Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events*", Order No. EA-12-049, ADAMS Number ML12054A735, Washington, D.C., March 12, 2012.
3. EPRI, "*Seismic Evaluation Guidance: Screening, Prioritization and Implementation Details (SPID) for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic*", Report Number 1025287, Palo Alto, CA, November, 2012.
4. U.S. NRC (Dean, W.), "*Final Determination Of Licensee Seismic Probabilistic Risk Assessments Under The Request For Information Pursuant To Title 10 Of The Code Of Federal Regulations 40.54(f) Regarding Recommendation 2.1 "Seismic" Of The Near-Term Task Force Review of Insights From The Fukushima Dai-ichi Accident*", Letter to all Power Reactor Licensees et al., Washington, D.C., October 27, 2015.
5. EPRI, "*High Frequency Program: Application Guidance for Functional Confirmation and Fragility Evaluation*", Report Number 3002004396, Palo Alto, CA, July 30, 2015.
6. U.S. NRC (Leeds, E), "*Screening and Prioritization Results Regarding Information Pursuant to Title 10 of the Code of Federal Regulations 50.54(f) Regarding Seismic Hazard Re-Evaluations for Recommendation 2.1 of the Near-Term Task Force Review of Insights from the Fukushima Dai-Ichi Accident*", Letter to all Power Reactor Licensees et al., Washington, D.C., May 9, 2014.
7. U.S. NRC, "*NUREG-1407: Procedural and Submittal Guidance for the Individual Plant Examination of External Events (IPEEE) for Severe Accident Vulnerabilities*", ADAMS Number ML063550238, Washington, D.C., June, 1991.
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10. U.S. NRC, "*NUREG/CR-0098: Development of Criteria for Seismic Review of Selected Nuclear Power Plants*", Washington, D.C., May 1978.
11. U.S. NRC, "*NUREG-1488: Revised Livermore Seismic Hazard Estimates for 69 Sites East of the Rocky Mountains*", Information Notice 94-32, Washington, D.C., April 29, 1994.
12. EPRI, "*EPRI NP-6395-D: Probabilistic Seismic Hazard Evaluations at Nuclear Plant Sites in the Central and Easter US: Resolution of the Charleston Earthquake Issue*", Palo Alto, CA, April, 1989.

13. EPRI, "*EPRI NP-6041-SL Revision 1: A Methodology for Assessment of Nuclear Plant Seismic Margin, Revision 1"*, Palo Alto, CA, August, 1991.

14. NEI, "*NEI 12-01 Revision 0: Guideline for Assessing Beyond-design-basis Accident Response Staffing and Communications Capabilities*", Washington, D.C., May, 2012.

15. EPRI, "*Seismic Evaluation Guidance: Augmented Approach for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic*", Report Number 3002000704, Palo Alto, CA, April, 2013.

16. EPRI, "*Seismic Probabilistic Risk Assessment Implementation Guide*", Report Number 3002000709, Palo Alto, CA, December, 2013

17. ASCE, "*ASCE/SEI 43-05: Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities*", ASCE Standards, Reston, VA, 2005.

18. ATC, "*ATC-63: Recommended Methodology for Quantification of Building System Performance and Response Parameters – 75% Interim Draft Report*", Redwood City, CA, 2007.

19. Luco, N.; Ellingwood, B.R.; Hamburger, R.O.; Hooper, J.D.; Kimball, J.K.; and Kircher, C.A., "*Risk-Targeted versus Current Seismic Design Maps for the Conterminous United States"*, at SEAOC 2007 Convention Proceedings, Squaw Creek, CA, 2007.

20. U.S. NRC. "*Implications of Updated Probabilistic Seismic Hazard Estimates In Central And Eastern United States On Existing Plants Generic Issue 199 (GI-199), Safety Risk Assessment*", Washington, DC, August 2010.

21. Kennedy, R. P., "*Overview of Methods for Seismic PRA and Margin Analysis Including Recent Innovations*", Proceedings of the Organization for Economic Co-operation and Development (OECD)-Nuclear Energy Agency (NEA) Workshop on Seismic Risk, Tokyo, Japan, August, 1999.

H.8 ACRONYM / TERM LIST

AC	Alternating Current
ADS	Automatic Depressurization System
AFUP	Annual Frequency of Unacceptable Performance
AFW	Auxiliary Feedwater
AMS	Alternate Mitigating Strategy
ASCE	American Society of Civil Engineers
ATC	Applied Technology Council
BWRs	Boiling Water Reactors
β	Logarithmic Standard Deviation in the Seismic Fragility
β_C	Composite Logarithmic Standard Deviation in the Seismic Fragility
β_R	Logarithmic Standard Deviation Representing the Aleatory (Randomness) Uncertainties in the Seismic Fragility
β_U	Logarithmic Standard Deviation Representing the Epistemic Uncertainties in the Seismic Fragility
$C_{X\%}$	The x^{th}-Percentile Conditional Probability of Unacceptable Performance
CP	Construction Permit
CDF	Core Damage Frequency
CRDMs	Control Rod Drive Mechanisms
DB	Design-Basis
DBE	Design Basis Earthquake
DC	Direct Current
EDG	Emergency Diesel Generator
ELAP	Extended Loss of AC Power
EPRI	Electric Power Research Institute
ESEP	Expedited Seismic Evaluation Process
FLEX	Diverse and Flexible Coping Strategies
GL	Generic Letter
GMRS	Ground Motion Response Spectrum
HCLPF	High Confidence of Low Probability of Failure

HF	High Frequency
IHS	IPEEE HCLPF Spectra
IPEEE	Individual Plant Examination of External Events
ISRS	In-Structure Response Spectrum
LERF	Large Early Release Frequency
LLNL	Lawrence Livermore National Laboratory
LUHS	Loss of Normal Access to the Ultimate Heat Sink
MBDBE	Mitigation of Beyond Design-Basis Events
MCE	Maximum Credible Earthquake
MSA	Mitigating Strategies Assessment
MSSHI	Mitigating Strategies Seismic Hazard Information
NEA	Nuclear Energy Agency
NEI	Nuclear Energy Institute
NRC	Nuclear Regulatory Commission
NSSS	Nuclear Steam Supply System
NTTF	Near-Term Task Force
OECD	Organization for the Economic Co-operation and Development
OIP	Overall Integrated Plan
PGA	Peak Ground Acceleration
PORVs	Power-Operated Relief Valves (PORVs)
PSHA	Probabilistic Seismic Hazard Analysis
RCIC	Reactor Core Isolation Cooling
RCPs	Reactor Coolant Pumps
RCS	Reactor Coolant System
RLE	Review Level Earthquake
RLGM	Review Level Ground Motion
RPV	Reactor Pressure Vessel
SCDF	Seismically-Induced Core Damage Frequency

SEAOC	Structural Engineers Association of California
SERs	Staff Evaluation Reports
SFP	Spent Fuel Pool
SLERF	Seismically-Induced Large Early Release Frequency
SMA	Seismic Margin Assessment
SPRA	Seismic Probabilistic Risk Assessment
SSCs	Structures, Systems and Components
SSE	Safe Shutdown Earthquake (synonymous with the term “Design Basis Earthquake” or DBE used by some plants)
SMA	Seismic Margin Assessment
SEL	Seismic Equipment List
UHRS	Uniform Hazard Response Spectra