Plan for the Development of a Methodology for Seismically Induced Fires and Floods

Contents

1.0 OBJECTIVE

The objective of this document is to provide a detailed plan for the initiation of the activities needed to develop a probabilistic risk assessment (PRA) methodology for assessing seismically induced fires and floods.

2.0 BACKGROUND

The Near Term Task Force (Task Force) recommended that the US Nuclear Regulatory Commission (NRC), as part of the longer term review, evaluate potential enhancements to the capability to prevent or mitigate seismically induced fires and floods. This recommendation was prioritized as Tier 3 in SECY 11-0137 because longer term staff evaluation was required to support a regulatory action. In the SRM to SECY 11-0137, the Commission agreed with the Tier 3 prioritization of Recommendation 3, but directed the staff to initiate a PRA methodology to evaluate potential enhancements to the capability to prevent or mitigate seismically induced fires and floods as part of Tier 1 activities. Therefore, the prerequisite activity to initiate development of an appropriate PRA methodology should be started without unnecessary delay, while the remainder of Recommendation 3 activities remained prioritized as Tier 3.

In SECY 12-0025, the staff provided a summary of preplanning activities necessary to develop a framework for the development of a more detailed project plan to address development of a PRA method for seismically induced fires and floods. Pre-planning activities addressed several key aspects of this activity including the objectives of the methodology, intended users, stakeholder involvement, coordination with other initiatives, resource needs, and proposed schedule.

3.0 PLANNING SUMMARY

3.1 Define specific objectives of the methodology:

Purpose of the method

The purpose of this activity is to initiate development of a PRA method to assess seismically induced fires and floods as described in SRM SECY 11-0137. The method may rely on qualitative, quantitative, or a combination of quantitative and qualitative methods.

Because of the low frequencies that are expected for seismically induced fires and floods, the important aspect of the PRA method will be the ability to appropriately screen low frequency sequences. The initial screening approach will be used to remove low risk contributors from consideration and, subsequently allow analytical effort to be expended on more risk significant sequences to efficiently integrate PRA method into level 1 PRA.

A primary goal of the PRA method is to systematically identify the accident contexts that reactor plant systems, structures, and components (SSCs) would be called upon to mitigate seismically induced fires and floods. Therefore, the staff envisions that while a quantitative approach for assessing these hazards would be ideal, it may be possible to obtain sufficient information from qualitative approaches to gain insights for SSCs mitigation capability for seismically induced hazards.

Anticipated scope of the method

The original scope of the method will be limited to seismic events during full power operation. After the method is well established and understood for these events, the scope may be expanded to include events during other operational modes and spent fuel pools. If there are any plant outliers for other operational modes or spent fuel pools identified during Tier 1 walkdowns and assessments, those individual cases can be quantitatively analyzed by PRA methods if needed. This incremental approach will allow the staff to make progress in what is believed to be the more risk significant operational modes while minimizing near term resource needs.

Potential risk criteria

Current risk criteria (e.g. core damage frequency and fission product release frequency) and conventional risk importance measures (risk achievement worth, risk reduction worth, etc.), will be used for the assessment of enhancements to the capability to prevent or mitigate seismically induced fires and floods. This ensures consistency with other routine approaches and enables seismically induced fires and floods to be evaluated in a manner consistent with other hazards. The PRA method will include the assessment of the effects of mitigation capability alternatives for SSCs, including fire suppression capability and alternative means to maintain critical safety functions.

Intended users

An important aspect of this effort includes the participation and coordination with PRA standards development organizations to better identify the intended users. Therefore, it is expected that as the staff approach to resolving NTTF recommendation matures, the intended users of the method would be identified. However, it is expected that internal NRC staff, as well as external stakeholders would benefit from the availability of this methodology. For example, the staff believes that a PRA method for seismically induced hazards may be useful to the NRC staff in prioritizing activities and assessing potential generic safety issues and to industry users to improve the state of practice in seismic risk assessments and the identification of plant specific vulnerabilities.

3.2 Identify internal and external stakeholders and assess their level of needed involvement for the development of the PRA methodology.

Internal stakeholders to the NRC would include licensing organizations in the Office of Nuclear Reactor Regulation (NRR) and the Office of New Reactors (NRO) that are involved with PRA Applications. It is expected that external stakeholders, that might include industry organizations such as NEI and EPRI, would contribute as the methodology is shared with the public for their review and comments. The staff will also use consider direct engagement with EPRI under the joint EPRI/NRC memorandum of understanding for cooperative nuclear safety research in the PRA area.

In addition, as discussed in the previous section, participation and coordination with PRA standards development organizations would better define the external involvement needed for the development of the method.

3.3 Information gathering

The staff performed a limited literature search that included information from nuclear power plant (NPP) operating experience, international data and academic research (See Appendix). Based on the search results, the staff concluded that data and methods publicly available for seismically induced fires are relevant to public and domestic structures but are less relevant to NPPs. Furthermore, sufficient data is not available for seismically induced floods.

An NRC/EPRI joint report titled “Fire PRA Methodology for Nuclear Power Facilities” (NUREG/CR-6850) published in 2005, includes a section on seismic-fire interactions assessment. However, as stated in Section 13, it does not provide a quantitative methodology:

> “This procedure does not provide a methodology for developing models and quantifying risk associated with fires caused by a severe seismic event. This is due to a

combination of limitations in the state of the art, and the perceived low level of risk from these fires."

The review of NPP operating experience included a sample of Individual Plant Examination of External Events (IPEEE) submittal documents. The information provided in the IPEEEs was in a greater part qualitative and the level of detail varied significantly from plant to plant. Based on the varied qualitative information provided, the NTTF concluded that a reevaluation of the closure of GSI-172[1] was warranted; however, it is important to note that available qualitative information provided in the IPEEE submittals for seismically induced fires and floods was examined and found that there is no evidence to indicate that these postulated events are risk significant.

The staff communicated with international organizations to assist in the development of the methodology. Responses to our outreach activity were received from Japan, Korea, Finland, France, Hungary, Spain, UK and Canada. In general, the international community, except for Canada, is not explicitly addressing seismically induced fires and floods but is very interested on sharing any information. Canada regulatory standards require their licensees to perform a walkdown activity as part of a probabilistic safety assessment (PSA)-based Seismic Margins Analysis (SMA) or seismic PSA that do consider the question of seismically induced fires and floods.

3.4 Coordination with other NRC initiatives:

The NTTF Recommendation 2.1 recommended that the NRC require licensees to reevaluate and upgrade as necessary the design-basis seismic and flooding protection of SSCs for each operating reactor. Moreover, the Task Force recommended the NRC to direct specific actions to ensure adequate protection from natural phenomena and containment and spent fuel integrity. The completion of two of those specific actions, NTTF Recommendations 2.1[2] and walkdowns conducted per 2.3[3], will provide new information on flooding assessments and new seismic risk evaluations for high priority plants in the central and eastern US.

Although activities associated with Recommendations 2.1 and 2.3 will be most relevant to resolution of Recommendation 3, design and licensing basis changes associated with beyond design basis external hazard mitigation equipment (Recommendation 4.2), BWR venting capability (Recommendation 5.1), and spent fuel pool instrumentation (Recommendation 7.1)

[1] Generic Safety Issue (GSI)-172, "Multiple System Responses Program (MSRP)," to address 21 potential safety concerns that were raised by the Advisory Committee on Reactor Safeguards (ACRS) during the resolution of USI A-17, "Systems Interactions in Nuclear Power Plants"; USI A-46, "Seismic Qualification of Equipment in Operating Plants"; and USI A-47, "Safety Implications of Control Systems."

[2] Recommendation 2.1 - Request licensees to reevaluate the seismic and flooding hazards at their sites against current NRC requirements and guidance, and if necessary, update the design basis and SSCs important to safety to protect against the updated hazards.

[3] Recommendation 2.3 - Request licensees to perform seismic and flood protection walkdowns to identify and address plant-specific vulnerabilities and verify the adequacy of monitoring and maintenance for protection features such as watertight barriers and seals in the interim period until longer term actions are completed to update the design basis for external events.

have the potential to impact plant-specific responses to seismically induced fires and flooding. These activities will be completed no later than December 31, 2016. Once sufficient information has been obtained from these activities (2015-2016 timeframe), the staff will re-evaluate NTTF Recommendation 3. This evaluation will be based on experience gained in developing a PRA methodology for seismically induced fires and floods and insights derived from Recommendation 2.1, 2.3, and 4.2 activities.

4.0 PLAN

Even though the staff has limited resources available to support new fire and external hazard PRA activities, the staff plans to dedicate resources to the method development activity at a level that will not preclude accomplishment of other high priority work in the fire and external hazard area (e.g., development of new NFPA-805 fire and external hazard Standardized Plant Analysis Risk models). The staff plans to focus method development activities in (a) coordination with standards development organization and (b) perform a feasibility scoping study.

Coordination with Standards Development Organizations

The coordination with standards development organizations will include staff participation on a working group of the ASME/ANS Joint Committee on Nuclear Risk Management (JCNRM). Subsequent to the Fukushima accident, the JCNRM started a project team to evaluate what other events the standard should address in terms of concurrent events. The project team recommendations will be developed into a Working Group to evaluate how to revise ASME/ANS RA-S-2009, "Standard for Level 1/Large Early Release Frequency Probabilistic Risk Assessment for Nuclear Power Plant Applications" including developing the necessary requirements to more explicitly address seismically induced fires and floods and other concurrent events.

Perform a Feasibility Scoping Study

The feasibility scoping study will identify issues associated with the risk assessment of multiple concurrent hazards and evaluate available PRA methods within this context. This study should identify already available data, relevant to the nuclear industry, on seismically induced fires and floods. The research should consider the available data in terms of the specific topics, scope, and strengths and limitations of each known method/approach. It is important that the study include enough information to provide an understanding on issues that were specifically addressed in the past and what tools were used in each instance. The understanding of past available data will provide the opportunity to anticipate existing limitations and challenges that might include, among others, the ability to treat simultaneous events, events over time, and combinatorial effects of multiple events.

An initial screening method to assess risk contribution should be used to remove low risk contributors from consideration. An evaluation of the screening method(s) used should be provided to demonstrate its suitability. Subsequent to the initial screening, a more detailed qualitative analysis should be performed to assess the information gathered and determine if it is appropriate to use an existent PRA methodology as is, a modified PRA methodology that will integrate any specific needs not available in existent ones, or if a development of a new method is warranted.

There are some other overall challenges that need consideration. Because each NPP is expected to do an evaluation of the site specific risk of seismically induced fires and floods (Recommendation 2.1 and 2.3) before the PRA methodology is finalized, it will be a challenge to balance the efforts to prevent or minimize rework associated with identifying the scope of SSCs for a given NPP. The staff would also need to consider (1) that if the methodology is used later on, the results available need to be carefully analyzed to ensure that the information is still compatible with what the methodology prescribes and (2) the need for continued method development subsequent to the later Re-evaluation of Recommendation 3.

In general, this study would provide information regarding the capabilities of traditional and advanced risk assessment methods (e.g., linked event tree-fault tree, dynamic simulation-based approaches) for accident scenarios where issues such as event timing, dependencies, and concurrency can influence risk significance. This study would also include an evaluation of the current state-of-the-art for addressing seismically induced fires and floods and, more generally, concurrent hazards. It should be noted that PRA method study development assume the availability of existing seismic and fire hazard PRA models consistent with the current state of the art.

5.0 ACTIVITIES AND RESOURCES

The following activities are planned:

I. Participate in Standards Development Working Group for Multiple Concurrent Hazards.

II. Conduct PRA Method Feasibility Scoping Study for Concurrent Hazards (Starting in FY2013, for duration of two years).

The tasks to be performed and documented include the following:

1. Develop a project plan that defines objectives, challenges, and scope.
2. Identify feasible method (including alternatives).
3. Identify potential screening criteria for seismically induced hazards.
4. Define data and input needs.
5. Obtain and document feedback from industry experts in relevant fields (such as seismic, flooding, etc.)
6. Provide recommendations and limitations.

III. Re-evaluate approach for addressing Recommendation 3. This re-evaluation would result in either:

- Identification of further information needed to support a decision
- Recommendation for specific regulatory action
- Recommendation for no further work.

Appendix A
Search for Information on
Seismically Induced Fires and Floods

Contents

1.0 Objective

To the extent practical, gather relevant information, including nuclear power plant operating experience, general seismic experience, international data, and academic research for the development of a Probabilistic Risk Analysis (PRA) methodology on seismically induced fires and floods. This effort is in response to Staff Requirements Memorandum (SRM)-SECY-11-0117, "Charter for the Nuclear Regulatory Commission Steering Committee to Conduct a Longer-Term Review of the Events in Japan."

2.0 Information Gathering

The literature review of NPP operating experience, general seismic experience, international data, and academic research at least include a literature research on seismically induced fires and seismically induced floods. The research activities also included targeted search on the topic and EPRI, IAEA, Japan, seismic events for NPPs, and IPEEE requirements and responses (if any), among others.

3.0 Recent EPRI Report and Events

*1. **EPRI issued a report NP-6989 in September 1990, titled "Survey of Earthquake-induced Fires in Electric Power and Industrial Facilities."***

This document examined 18 earthquakes and 108 facilities. There were 4 sites where a fire ignition followed an earthquake. Expanding the time period of this report through 2012 could be useful.

The report conclusion states:

"Of the 108 power or industrial operation sites investigated, there are four instances of earthquake-induced fire. Two of the instances involve electrical fires caused by arcing in high voltage equipment. One instance is a chemical fire in a laboratory, and one (perhaps the least well understood), appears to be ignition of oil-soaked insulation on a steam line in a power plant. The incidents of fire identified were all localized events within the facilities in which they occurred and did not appear to result in significant damage. "

*2. **2007 seismic event at Kashiwazaki-Kariwa NPP***

The magnitude of the event was 6.6 in Richter scale. The maximum pga at the site was estimated to be 0.26g. (This is in BIN-1 of SPAR-AHZ models, with relatively small seismic failure probabilities for most SSC - except offsite power). This earthquake triggered an automatic shutdown of operating units on this multi-unit site.

A small fire occurred in an electrical transformer in the switchyard of Unit 3. The fire was extinguished in two hours. There was also damage to fire protection system piping (leakage). This event is discussed in the NRC's Operating Experience (OpE) database. The failures are considered benign with respect to their effect on the actual safe shutdown of the plant.

3. ***December, 2006 Taiwanese Earthquake on Maanshan Nuclear Power Station (MNPS)***

On December 26, 2006, a series of earthquakes occurred near Hengchun, Taiwan where MNPS is located. Two large earthquakes occurred within 8 minutes of each other and were both of magnitude 7.0. One unit was manually tripped; the other remained operating. There was an accumulation of dust inside the ventilation pipe in the ceiling of the main control room.

During and following the earthquake, this dust floated down from the top of the ceiling into the main control room. As noted earlier, the operators misinterpreted the dust to be smoke from a fire and decided to trip one of the reactors as a safety precaution.

The design basis earthquake for MNPS is the largest known earthquake that has occurred on the nearest known fault. The largest earthquake that has occurred was a magnitude 8.3 quake in 1920, and the nearest fault is about 35 km from MNPS. An earthquake of this magnitude at this location would lead to ground accelerations at MNPS of slightly less than 0.4g (this magnitude earthquake is modeled in BIN-2 of SPAR-AHZ models, where non-safety related equipment credited in PRA models may have more than small probability of seismic failure). This design basis earthquake level is very high compared to other NPPs we are familiar with, in general.

4. A recent proprietary work by EPRI includes a process for identifying and addressing potential seismically-induced internal fires and seismically-induced internal floods in a commercial nuclear power plant seismic PRA.

5. ***March 11, 2011 Onagawa Event***

On March 11, 2011, a magnitude 8.9-9 mega thrust earthquake off the north eastern coast of Japan and triggered a large tsunami, with wave heights reaching up to 10m. Eleven reactors at four sites near Japan's northeast coast were shut down per seismic emergency procedures.

As a result of the March 11, 2011 earthquake, the Onagawa Nuclear Power Plant experienced a seismically induced arcing fault in a non-emergency M/C switchgear cabinet (6.9 kV). The event caused failure of the startup transformers, an instantaneous trip of the Emergency bus, failure of synchronous detection circuits for the diesel generator, damage to the cables above the cabinet and damage to 10 sections in the cabinet row.

The event was initiated by Magna-Blast Breakers, which were in a hanging position, not fixed to the floor. These non-safety related breakers began to jostle during the 9.0 magnitude earthquake which resulted in misalignment and damage to the circuit breaker connections. This damage and contact with the internals of the cabinet resulted in a short circuit to ground and a resulting high energy arcing fault. The heat due to arcing resulted in a fire within the cabinet.

This fire was complicated by the earthquake and resulting tsunami which hindered the efforts of the fire brigade as most access paths to the site were damaged. The onsite fire brigade could not identify the location of the fire due to heavy smoke. These complications prolonged the fire duration and control abilities at the plant. The fire lasted for 7 hours.

4.0 Excerpts from NRC Documents and Other Standards

Excerpts from NUREG-1407

NUREG-1407: "Procedural and Submittal Guidance for the Individual Plant Examination of External Events (IPEEE) for Severe Accident Vulnerabilities", June 1991

"6.3.2 Coordination Among External Events Programs

The issue of integration between external events primarily involves interactions between seismic events and fires and seismic events and floods. Seismically induced fires and floods are to be addressed as part of the IPEEE. The effects of seismically induced fires and the impact of inadvertent actuation of fire protection systems on safety systems should be addressed. The effects of seismically induced external flooding and internal flooding on plant safety should be included. The scope of the evaluation of seismically induced floods, in addition to that of the external sources of water (e.g., tanks, upstream dams), should include the evaluation of some internal flooding consistent with the discussion in Appendix I of EPRI NP-6041. The coordination between the seismic and the fire or flood analysts should be based on the following:

1. The seismic analysts should generally search for and identify the initiating events (certain specific seismically initiated failures of equipment or structures) that can cause fires or floods, and

2. The seismic and fire or flood analysts should also discuss other concurrent seismically induced failures or possible effects on human actions and then, proceed to complete the rest of the IPEEE analysis.

The coordination should include a meeting, prior to seismic walkdown, in which the fire and flood analysts discuss the key issues, how the analysis will be done, and what to look for. The fire or flood analyst may need to participate in parts of the seismic walkdown or revisit the areas identified during the seismic walkdown to grasp the issues from the seismic-capacity point of view."

Excerpts from NUREG-1742

NUREG-1742: Perspectives Gained from the IPEEE Program, 2001.

"2.3.1.7 Seismic-Fire and Seismic-Flood Evaluations

All licensees qualitatively examined seismic-fire interaction issues as part of their assessment of fire risk. To varying degrees, such examinations have included the potential for, and effects of, seismically initiated fires, seismic actuation of fire suppression systems, and degradation of fire suppression systems from seismic events. Some licensees undertook quantitative assessments of component capacities related to seismic-fire and seismic-flood interactions. A few licensees performed some form of SPRA study for seismic-fire and/or seismic-flood initiating events and documented it in their submittal.

In most of the submittals, licensees included seismic-fire and seismic-flood considerations within the scope of their overall seismic walkdown effort. The seismically induced fire interactions were generally addressed by first identifying combustion sources (e.g., hydrogen lines, oil tanks) and then performing walkdowns to evaluate whether these sources are both significant hazards and seismically vulnerable. Some of the seismic fire interaction evaluations have led to a number of fixes, such as restraining gas cylinders, strengthening anchorages for fuel oil tanks, and, where feasible, relocating combustion sources away from safety equipment. The most consistent strong points of these evaluations appear to be the treatment of inadvertent actuation of fire suppression systems and the identification of potential interaction concerns involving safety equipment. However, the scope, and detail of efforts to address seismic-fire and seismic-flood issues have varied significantly among the IPEEE submittals. Some licensees did not include any seismic-fire or seismic-flood evaluation in their submittal, but provided some information on these topics in RAI responses. In most cases, licensees have limited their seismic-fire and seismic-flood evaluations exclusively to assessing direct impacts on safe shutdown equipment, and some submittals did not consider the potential for seismically induced loss of fire suppression systems.

Some licensees have sought to include all relevant plant areas and equipment in their evaluations of the potential and effects of seismic-fire and seismic-flood events. Such relevant items include, for instance, fire suppression system components and non-safety piping and tanks, which may not be part of the seismic plant model or safe shutdown equipment list, but are nonetheless important and/or may have indirect effects on safety equipment.

In many of the IPEEE submittals, the seismic-fire and/or seismic-flood interaction evaluations revealed concerns and, in a number of instances, resulted in significant plant improvements. Some of the relevant improvements include strengthening component anchorages, replacing vulnerable (e.g., mercury) relays and switches, restraining gas cylinders, waterproofing, replacing sight glass tubes, and implementing procedures to properly secure transient fire-protection equipment.

In one instance, the licensee evaluated the potential for seismically induced toxic chemical release, as part of its seismic-interactions walkdown. As a result, the licensee identified a plant-specific improvement related to strengthening the anchorage of an ammonia storage tank.

Information on this issue for individual plants can be found in Table 2.12 of Volume 2 of this report."

Excerpts from IAEA SSG-3

IAEA Safety Standards No. SSG-3, 'Development and Application of Level 1 Probabilistic Safety Assessment for Nuclear Power Plants", 2010.

"8.8. As seismic hazards appear to be important contributors to core damage frequency in many Level 1 PSAs, a detailed analysis should be performed. However, in order to limit the effort required for Level 1 PSA for seismic hazards, it is possible to perform a bounding analysis for seismic hazards of a certain range. The secondary effects of seismic hazards (e.g. seismically induced fires and floods) should also be considered at this stage….

8.66. The potential for seismically induced fires and floods should also be included in the focus of the walkdown….

8.92. Seismically induced fires and floods should be included in the Level 1 PSA model for seismic hazards, unless it is clearly justified that other seismic damage bounds additional effects from seismically induced fire and floods…"

Excerpts from SECY-11-0093 – Enclosure- " The Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident." *July 2011, ML111861807*

This document discusses protection from concurrent related events in Section 4.1.2 and provides recommendation 3 which led to the current work in the present document.

Recommendation 3

The Task Force recommends, as part of the longer term review, that the NRC evaluate potential enhancements to the capability to prevent or mitigate seismically induced fires and floods."

Samples Taken from IPEEE Submittals

Various IPEEE submittals from different regions of the USA were examined to see how seismically induced fires and floods, were addressed, as requested by NUREG-1407 (see above). The documentation provided in IPEEE submittals varies from one plant to the other, but is in general, the information submitted is in summary form. A few examples are provided below.

San Onofre IPEEE

- Section 3.3.4 Seismic Fire/Flood Interactions and Walkdown (pdf pages 66-76).

  Evaluation of potential seismic-fire and seismic-flood interactions.

  The purpose of this evaluation is to:

  - *identify any potential for a seismic-induced fire or seismic-induced flood that could damage equipment or structures that are important to safety during or after a seismic event, and*
  - *determine whether any identified damaging seismic-induced fire or floods are vulnerabilities and to assess viable mitigating measures.*

  The IPEEE concluded that

  *A systematic evaluation and walkdown of potential seismic-induced fires or floods was performed for the SONGS **2/3** IPEEE. These evaluations included issues such as fires due to potential sources of hydrogen, floods due to multiple actuations of fire suppression systems, and toxic gas release from the ammonia tank. Based on this evaluation, there are no potential seismic-induced fire or flood sources that will affect safety equipment needed for shutdown during or after a seismic event.*

Diablo Canyon IPEEE

- 3.1.3.8 Seismically-Induced Fires
- 3.1.3.10 Seismically-Induced Floods
  (pdf pages 36-37)

  ***3.1.3.8** Seismically Induced Fires*
  Seismically induced fires were assessed as part of the LTSP. The potential for seismically induced fires was also considered in the fire risk scoping study evaluation (Section 4.8) following the approach outlined in the EPRI Fire-Induced Vulnerability Evaluation final report (Reference 3-19).

  ***3.1.3.9** Seismic Events Success Criteria*

System success criteria and mission times were generally left the same as those used in the internal events analysis. Two exceptions are the mission times for the diesel generator system and the fuel oil transfer system. These mission times were changed from 6 to 24 hours. This conservatively models the longer recovery time that may be required to restore offsite power following a seismic initiator.

***3.1.3.10** Seismically Induced Floods*
The internal flooding scenarios previously analyzed (Reference 3-20) were reviewed and none was determined to present unique seismic problems. Additionally, a number of the seismic top events include contributing causes of piping failure or other component failures which considers potential seismic flooding scenarios. Seismically induced fires, seismic actuation of fire suppression systems, and seismic degradation of fire suppression systems are addressed in Sections 4.8.1.1 to 4.8.1.3.

- **4.8.1 Seismic/Fire Interactions (pdf pages 234-240)**

The EPRI-suggested response to the Sandia Fire Risk Scoping Study issue related to seismic/fire interactions consists of the following three aspects:

1. Seismically Induced Fires
2. Seismic Actuation of Fire Suppression Systems
3. Seismic Degradation of Fire Suppression Systems

The IPEEE fire walkdown discussed in Section 4.2 included a seismic/fire component. This portion of the walkdown activities verified, through visual examination, the pertinent details in identified fire areas relevant to each of the three aspects identified above.

Palo Verde IPEEE

- 4.8 Sandia Fire Risk Scoping study Issues
- 4.8.1 Seismic/Fire Interactions

*Seismic/fire interactions were addressed in Section **3.3** of Reference 4.10.11, "Prescreening and Walkdown of Palo Verde Nuclear Generating Station for Seismic IPEEE." No concerns or vulnerabilities were identified. In addition, NRC Information Notice 94-12, Effects of Fire Protection System Actuation on Safety-Related Equipment," was addressed. No lessons learned applicable to Palo Verde were identified. See Ref. 4.10.12, which is also appended to Ref. 4.10.6.*

The IPEEE did not identify any vulnerabilities in the areas examined for seismically-induced fire and flooding.

Limerick IPEEE

4.8.2.1 Seismic/Fire Interactions (pdf page 211)

The seismic/fire interactions issue consists of three elements:

(1) seismically induced fires;
(2) seismic actuation of fire suppression systems;
(3) seismic degradation of fire suppression systems.

These were examined and discussed in the report. No vulnerabilities were identified.

DC Cook IPEEE

3.2.7 Seismically Induced Flooding (pdf page 40)

Flooding due to tank and pipe rupture was examined as part of the internal flooding analysis. AEPSC flooding calculations were performed in response to ***EE*** *Notices 83-41 and 8749. They addressed worst case flooding scenarios which could occur as a result of a seismic event, and concluded that safety equipment in the auxiliary building was not vulnerable to flooding events,*

Flooding due to the rupture of non-seismic fire protection piping was also reviewed. Overall, seismically induced flooding does not pose a hazard at the Cook Nuclear Plant.

Seismic-Fire interactions were briefly discussed in section 4.8.5 (pdf page 88).

The IPEEE concludes that

Overall, seismically induced flooding does not pose a hazard at the Cook Nuclear Plant.

Also, no seismically-induced fire vulnerabilities were found.

5.0 Seismically-Induced External Floods

Seismically induced external flooding (such as failure of upstream dams) was the subject of a recent generic issue, GI-204, for which a risk assessment was to be performed:

> External floods; GI-204 Flooding of Nuclear Power Plant Sites Following Upstream Dam Failure.

This generic issue has been transferred to NTFF Recommendation 2.1. After completion of this activity, the impact of the seismic event that caused the dam failure on the plant to cause internal fires and or internal floods should be examined in the context of Recommendation 3 work.

It is worth mentioning that the actuarial data and dam hazard statistics (as reported by Bureau of Reclamation database) indicate that the contribution of seismic events to dam failures is insignificant, as a percentage. Overtopping and other failures dominate the failure frequency. However, the point mentioned above should be examined in risk perspective. The following reference is included as a starting point for dam failures.

http://www.usbr.gov/ssle/damsafety/Risk/pfma/TabJ-SeismicFailureModes.pdf

6.0 Information from International Counterparts

The staff communicated with international organizations to assist in the development of the methodology. Responses to our outreach activity were received from Japan, Korea, Finland, France, Hungary, Spain, UK and Canada. In general, the international community, except for Canada, is not explicitly addressing seismically induced fires and floods but is very interested on sharing any information. Canada regulatory standards require their licensees to perform a walkdown activity as part of a probabilistic safety assessment (PSA)-based SMA or seismic PSA that do consider the question of seismically induced fires and floods.

7.0 Reports and Other Documents

The staff identified and examined the following documents as part of internal information gathering:

1. NUREG/CR-6850 EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities Volume 2: Detailed Methodology 2005. Chapter 13: Seismic-Fire Interactions Assessment (Task 13)

2. NUREG/CR-6544 A Methodology for Analyzing Precursors to Earthquake-Initiated and Fire-Initiated Accident Sequences 1998

3. NUREG-1407 Procedural and Submittal Guidance for the Individual Plant Examination of External Events (IPEEE) for Severe Accident Vulnerabilities 1991

4. NUREG-1742 Vol. 1 Perspectives gained from the Individual Plant Examination of External Events (IPEEE) Program 2001

5. ASME ANS RA-Sa–2009

6. LA-UR-06052: A Method for Evaluating Fire after Earthquake Scenarios for Single Buildings_1;

7. LA-UR-11-01857 Modeling the Number of Ignitions Following an Earthquake: Developing Prediction Limits for Overdispersed Count Data

8. *NUREG/CR-5042 Evaluation of External Hazards to Nuclear Power Plants in the United States, 1987.*

9. NUREG/CR-4331: "An Approach to the Quantification of Seismic Margins in Nuclear Power Plants", Lawrence Livermore National Laboratory, Livermore, CA. (1985)

10. NRC Information Notice 94-12. Insights gained from resolving generic issue 57: Effects of fire protection system actuation on safety-related equipment.

11. IAEA Safety Standards No. SSG-3, 'Development and Application of Level 1 Probabilistic Safety Assessment for Nuclear Power Plants", 2010.

12. NUREG-1742: Perspectives Gained from the IPEEE Program, 2001.

13. http://fire.nist.gov/bfrlpubs/fire03/PDF/f03055.pdf, "Development of Seismic-induced Fire Risk Assessment Method for a Building"

14. http://geology.gsapubs.org/content/30/11/1007.short, External flooding due to groundwater in Chile.

15. http://www.sciencedirect.com/science/article/pii/S0029549397003373 -- Preliminary perspectives gained from individual plant examination of external events (IPEEE) seismic and fire submittal review.

16. http://www.sciencedirect.com/science/article/pii/S0951832098000180 -- Issues related to structural aging in probabilistic risk assessment in nuclear power plants.

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