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Southern Nuclear PRA Calculation

Calculation Number:
PRA-BC-F-11-006

Plant: JOSEPH M. FARLEY NUCLEAR PLANT	Unit: ☐ 1 ☐ 2 ☒ 1 & 2	Discipline: RIE Department
Subject/Title: Farley Fire PRA Task 13, Seismic-fire Interactions Assessment		
Objective: The purpose of this document is to evaluate the risk for Farley Nuclear Plant Units 1 and 2 with respect to NUREG/CR-6850 Task 13, *SEISMIC-FIRE INTERACTIONS ASSESSMENT*.		
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Contents

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☐ Non-Safety-Significant (NS)

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Notes:

Purpose of Calculation

The purpose of this document is to evaluate the risk for Farley Nuclear Plant Units 1 and 2 with respect to NUREG/CR-6850 Task 13, *SEISMIC-FIRE INTERACTIONS ASSESSMENT.*

Summary of Results

The result of this qualitative analysis is that the risk of seismic induced fires is negligible compared to the risk of fire or seismic events occurring separately.

Methodology

The methodology and guidance used to perform the qualitative risk assessment is outlined in Task 13 in NUREG/CR-6850 [1].

Assumptions

No specific assumptions are made in the conduct of this task.

References

See the references in the **Body of Calculation.**

Body of Calculation

RECORD OF VERSIONS		
VERSION No.	**DATE**	**DESCRIPTION OF CHANGES**
1	9.15.2011	Initial Release

TABLE OF CONTENTS

1.0 SCOPE

The purpose of this document is to evaluate the risk for Farley Nuclear Plant Units 1 and 2 with respect to NUREG/CR-6850 [Ref. 1] Task 13, *SEISMIC-FIRE INTERACTIONS ASSESSMENT.*

Task 13 identifies the following issues:

- Seismically induced fires
- Degradation of fire suppression systems and features
- Spurious actuation of suppression and/or detection systems
- Degradation of manual firefighting effectiveness

This evaluation is based on the information contained in the Farley Unit 1 and 2 IPEEE (submitted to the NRC on June 28, 1995 [Ref. 2]).

As discussed in NUREG-6850, Task 13, Seismic-Fire Interactions Assessment, the use of a qualitative, walk-down based approach, is the recommended practice for assessing the low risk of an earthquake initiating a challenging fire or degrading fire protection systems. This methodology is consistent with the guidance provided in:

- ANSI/ANS-58.23-2007, American National Standard, Fire PRA Methodology.

- NUREG/CR-5088, *Fire Risk Scoping Study: Investigation of Nuclear Power Plant Fire Risk, Including Previously Unaddressed Issues*, USNRC, January 1989.

- *Fire-Induced Vulnerability Evaluation (FIVE)*, Electric Power Research Institute (EPRI), Rev. 1, September 1993. TR-100370.

- *Fire PRA Implementation Guide*, Electric Power Research Institute (EPRI), 1995. TR-105928.

2.0 EVALUATION

This evaluation generally elaborates on the previous assessment results developed in the Farley IPEEE [Ref. 2], Sections 3 and 4. ASME/ANS RA-Sa-2009 (i.e., the fire PRA standard) requires that the plant be reviewed for the presence of "fire ignition source scenarios that might arise as the result of an earthquake that would be unique from those postulated during the general [fire PRA] analysis." That is, it is in general not necessary to consider seismically induced fire ignition sources that are already considered in the fire PRA, as the corresponding risk is expected to be bounded. The reason this is valid is because it is expected that the frequency of a fire being caused by a given ignition source by random causes will be greater than it being caused by the occurrence of an earthquake (i.e., the frequency of fire is higher than the frequency of a damaging earthquake). Specifically, the Fire PRA standard includes the following high level requirement for seismic fires (SF):

SF-A: "The Fire PRA shall include a qualitative assessment of potential seismic/fire interaction issues in the Fire PRA."
This high level requirement is supported by a five supporting requirements primarily intended to qualitatively assess if the scenarios postulated in the Fire PRA bound the risk associated with fires generated by a seismic event. In practice however, the risk associated with scenarios resulting from seismic induced fire events may also be captured in a seismic PRA. Consequently, the scope of both Fire and Seismic PRA studies are considered in identifying seismically induced fire scenarios, whose risk contribution may need to be assessed.

It is important to understand the relationship between typical fire scenarios postulated in a Fire PRA (fires not resulting from seismic events) and those fires resulting from seismic activity. Consider first that seismic failure modes are for the most part structural damage (e.g., deflection), anchorage failure (e.g., movement, toppling over), internal element failure (e.g., broken insulators, damage to racks), etc. The occurrence of these seismic failure modes, in addition to causing functional failure of the component, may then result in a fire (i.e., a fire is not considered a seismic failure mode). When a component is analyzed in a seismic PRA, there is a thorough assessment of all failure modes that could cause the component to lose functionality. If no seismic failure mode can be postulated, it means that the component is fully capable of performing its function (i.e., undamaged). In this case, it is no more likely to cause a fire in the hour following a seismic event than it is at any other randomly selected hour of its operation. Consequently, it is generally expected that fire impacts on plant systems and components following a fire event should be captured in the seismic PRA scenarios where the failure mode already captures the necessary impacts, or the evaluated fire scenarios, where the fire propagation may increase the number of impacts.

It can be argued that a post earthquake fire in a given zone would cause additional damage to other components, but again the risk contribution of that would be small relative to the damage caused by the earthquake. It should be noted that in a seismic PRA, all failures of similar components are considered completely coupled. If for example a bus fails, all similar busses also are assumed failed. If a wall falls on a bus, all similar walls fall on all similar busses. Under such an approach, it really doesn't matter that one or more fires could start since loss of functionality of the affected components has been considered.

Because of the high common cause failure (CCF) coupling factor (1.0) between similar seismic failures as much damage as possible has been postulated regardless of a fire (i.e., Fire PRA scenarios usually consider impact of individual cables in the electrical distribution system instead of assuming failure of all busses). Components designed to the safe shutdown earthquake (SSE) will only suffer seismic failure at well over the SSE. Even those items that are not designed for the SSE are very unlikely to fail at the operating basis earthquake (OBE) since the important systems and components of the plant can survive an OBE. Since the seismic failure of one train will fail all identical trains with conditional probability of 1.0, and multiple fires would have to start in order to have the same effect, it is clear that the contribution from the seismic failures would dominate.

Finally, although seismic PRAs assume that seismic failure of similar components are completely coupled (i.e., dependent), there is no technical basis for concluding that consequential fires resulting from seismic failure of similar components are likewise coupled. That is, while the occurrence of damage to multiple identical components is assumed to occur, the ignition of fire as a result of the damage to the components is taken to be largely independent, and so the consequences of multiple fires from damage to components at the higher accelerations will be small compared to the direct damage to multiple components from the seismic event alone. Taken together, it can be concluded that the seismically-induced fire ignition frequency from any component designed for the OBE is small relative to the frequency of random fires from those components. Further, the seismic-induced multiple fire ignition frequency and the associated consequences from any components designed for the OBE is small relative to the frequency and consequences due directly to the seismic damage.

Consequently, the seismic-fire concern is limited only to whether there are any potential fire ignition events that can occur at low accelerations (which have a higher annual frequency) in the absence of seismically-induced damage, or affect (e.g. spuriously trigger) fire protection systems that would impact the ability for fire control and suppression. These would be the only conditions that could reasonably be expected to contribute to risk since the seismic event frequency times the conditional probability of fire (or multiple fires) could theoretically be more likely than the random occurrence of such fire(s). Therefore, this task is focused on identifying ignition sources that have a seismic failure mode at very low accelerations and that are not present in the absence of a seismic event (e.g., a flammable liquid cabinet, etc), and the plant response to such fires considering the effect that the seismic event could have on the detection and suppression capabilities.

2.1 SEISMICALLY INDUCED FIRES

As discussed above the process of identifying and describing potential post earthquake fire scenarios is limited to those triggered by ignition sources that are demonstrably and obviously weak (i.e., that have seismic failure mode at very low accelerations). It should be noted that these ignition sources are accounted for in the Fire PRA as part of fire scenarios in the absence of a seismic event. Recall that the Fire PRA captures the risk of both fixed and transient ignition sources, which generally should be the same ones generating a fire after a seismic event. Consistent with the approach of classifying fire scenarios in a Fire PRA, relevant post-earthquake fire scenarios are classified as fixed ignition source scenarios and transient ignition source scenarios. That is, those ignition sources that are permanently located in the different zones, and those that are temporarily brought into the zone.

This issue involves the potential for fires, inside or outside the plant, due to a significant seismic event. In addition to post earthquake fires associated with pipes or storage tanks containing flammable gasses or liquids, the concern is for the potential for fires arising from the failure of electrical equipment during an earthquake. This concern is due to unrestrained or inadequately restrained electrical equipment being physically displaced and causing electrical fires through physical damage to electrical cables and connections feeding power to the components. Further concern is that firefighting response may also be compromised and/or complicated by the seismic event. The evaluation of this question was performed for both units by SCS as part of the Unit 1 Unresolved Safety Issue (USI) A-46/IPEEE-Seismic walkdown [Ref. 2 and 3]. This issue was addressed in the IPEEE as follows:

Section 3, Seismic Analysis:

This section of the IPEEE described the methodology for performing the Reduced Scope Seismic Margins Assessment (SMA) for Farley Units 1 and 2. The reduced-scope SMA was performed in accordance with the guidelines of NUREG-1407 [4], the Seismic Qualification Utility Group (SQUG) Generic Implementation Procedure (GIP) [5] and the EPRI SMA methodology [6]. Walkdowns were performed by a qualified Seismic Review Team (SRT). The Unit 1 Seismic Review SSEL required a seismic capability walkdown of 498 components. The Unit 2 Seismic Review SSEL included 389 components.

All FNP Units 1 and 2 equipment included in the scope of IPEEE-Seismic was shown to possess a sufficient overall seismic capacity that the equipment can be screened out at the Review Level Earthquake (RLE) or SSE level of 0.1 g pga, or will be modified to achieve that capacity. All the components were evaluated for seismic capacity versus demand, in compliance with screening caveats, anchorage adequacy, seismic spatial interaction and flooding.

Cable and conduit raceways are, in general, judged to have a seismic capacity of at least 0.3 g pga by the SMA methodology. Based on the USI A-46 walkdown and analytical review, the conduit and raceway systems are screened out at the RLE of 0.1 g pga.

Section 3.1.4.7 and Section 4.8 Question 1, Seismic Fire Interactions, provided the following information:

There were no potential seismically induced fire concerns identified by the SRT during this walkdown or during the SSEL seismic capability walkdown. All gas- and liquid-storage vessels were adequately supported to prevent seismic interaction or damage. In addition there were no cases discovered wherein a flammable gas or liquid was stored in the same room with safety-related or SSEL equipment.

2.2 DEGRADATION OF FIRE SUPPRESSION SYSTEMS AND FEATURES

This issue primarily involves the potential that fire suppression systems may be unavailable following a seismic event. Degradation of fire suppression features and detection systems were addressed as follows:

Section 3.1.4.7 and Section 4.8 Question 3 Seismic Spatial Interactions, provided the following information:

The information provided in these sections confirms that fire suppression systems have been structurally installed in accordance with good industrial practice and have been reviewed for seismic considerations such that suppression system piping and components will not fail and damage SSD path components. It is also unlikely that leaking or cascading of the suppressant will result. The evaluation of this issue was performed for both units by SCS as part of the Unit 1 USI A-46/IPEEE-Seismic walkdown.

Supports for the fire suppression system piping are designed for Seismic Category I requirements to preclude damage that could incapacitate equipment. In addition, the seismic ruggedness of the fire suppression piping and components in areas containing Safe Shutdown Equipment List (SSEL) components was evaluated by the Safety Review Teams (SRTs) during the seismic capability walkdowns. Therefore, based on the engineering judgment of the SRTs, the FNP fire suppression system is considered adequate in regard to Seismic II/I considerations at the Review Level Earthquake of 0.1 g pga.

Additionally, responses were made to the INPO Event Report Level 1 11-1 for the Fukushima Daiichi Nuclear Station fuel damage event. Recommendation 4 requested Farley Nuclear Plant to perform walkdowns and inspections of important equipment needed to mitigate fire and flood events to identify the potential that the equipment's function could be lost during seismic events appropriate for the site. The request included developing mitigating strategies for identified vulnerabilities. As a minimum, the performance of walkdowns and inspection of important equipment (permanent and temporary) such as storage tanks, plant water intake structures, and fire and flood response equipment was requested; and the development of mitigating strategies to cope with the loss of that important function. Completion of the walkdowns and inspections were requested to be performed by April 13, 2011.

The Southern Nuclear Corporate Fire Protection group provided Plant Farley with a preliminary list of important areas and fire suppression equipment for consideration in responding to Recommendation 4. Plant Farley staff reviewed the Fire and Flood design basis with support from Southern Nuclear Corporate Engineering. Teams were assembled to walk down and inspect all accessible Structures, Systems, and Components (SSCs). "Guideline for Assessing Fire Suppression Capabilities" and "Guideline for Assessing Flood Mitigation" posted on the INPO website were used as primary guidance in performing the evaluations. The walkdowns focused on degraded material condition that could impact the ability of fire or flood mitigation equipment to function in the event of a seismic event. All accessible areas/rooms in and around the Auxiliary Buildings, Diesel Generator Building, Service Water Intake Structure, Turbine Buildings, Condensate Storage Tanks, Reactor Makeup Water Storage Tanks, Refueling Water Storage Tanks, Main and Auxiliary Transformers, Fire Pump House, Fire Protection Distribution, and portable firefighting equipment storage facilities were walked down by Plant Farley staff. Plant abnormal operating and emergency preparedness procedures were reviewed for feasibility in a design basis seismic event. Gaps and vulnerabilities were reviewed to complete the Recommendation 4 response.

The inspections and reviews show that Plant Farley has the equipment, procedures, and agreements to respond to design basis fire and flood events (i.e. no Gaps to existing requirements were identified). There is a general beyond-design-basis vulnerability associated with the plant's non-seismic fire protection structures, systems, and components, particularly with the buried Fire

Protection piping. Enhancement opportunities exist in responding to other beyond design basis considerations, procedure clarifications, equipment staging for seismic events, and housekeeping. The staff also recognized training opportunities for additional Severe Accident Mitigation Guidelines and accidents beyond design basis. Beyond basis seismic events will be addressed in the future Farley seismic PRA.

2.3 SPURIOUS ACTUATION OF SUPPRESSION OR DETECTION SYSTEMS

This issue primarily involves the possible actuation of one or more of the fixed-fire protection systems (detection and/or suppression) in the event of an earthquake. The Farley IPEEE addressed the verification that the design of the fire suppression systems considers the effects of inadvertent suppression system actuation and discharge on equipment which was credited as part of the seismic SSD path in a SMA and was not previously reviewed in the internal flooding design analysis or in addressing concerns such as those discussed in NRC I.E. Information Notice 83-41.

Section 3.1.4.7 and Section 4.8 Question 2, Spurious or Inadvertent Actuation of Fire Suppression, provided the following information:

Seismic walkdowns revealed that the systems were well constructed and well supported. The SRTs judged that, because the piping system is so well supported, inertia loads on the sprinkler heads would be negligible. The possibility of impact on sprinkler heads was also addressed by seismic capability engineers (SCEs) during the seismic capability walkdown. Based on the IPEEE documentation SSD path components will not be adversely affected by inadvertent actuation of the water suppression system. Safety-related components are either not located near a sprinkler head or the component has been designed for protection from unacceptable water damage. In addition, the SCEs have judged that inadvertent actuation of the sprinkler head due to a seismic event is not credible at FNP.

2.4 DEGRADATION OF MANUAL FIREFIGHTING EFFECTIVENESS

Sections 2 and 3 of EPRI TR-100370, Attachment 10.5, discuss fire barrier qualifications and manual firefighting effectiveness. Section 4.8 Question 3 of the Farley IPEEE provides a discussion of fire barrier qualifications and a description of fire brigade training and practice drills:

Section 2 of EPRI TR-100370, Fire Barrier Qualification, addresses the inclusion of fire barriers and components for fire barriers considered in the FIVE methodology in the plant surveillance program. Fire door inspection and maintenance programs are addressed in FNP Procedures FNP-1-FSP-65 and FNP-2-FSP-65. Penetration seal inspection and surveillance programs are addressed in procedures FNP-0-FSP-63 .O 1, 63.02, and 63.03, FNP-1-FSP-63.04 through FNP-1-FSP-63.18, and FNP-2-FSP-63.01 through FNP-2-FSP-63.18. The fire damper inspection and maintenance procedures are addressed in FNP-1-FSP-41.1 through -41.4; FNP-2-FSP-41.1 through -41.4 (testing); and FNP-1-FSP-65 and FNP-2-FSP-65 (visual inspection).

Section 3 of EPRI TR-100370, Manual Firefighting Effectiveness, addresses the methods of reporting fires, suppressing fires, organizing and training fire brigades, practice drills, and records. Portable extinguishers are located throughout the plant as described in FNP-1-FSP-9, FNP-2-FSP-9, and FNP-0-FSP-35, and plant personnel are trained in using fire extinguishers. Reporting of fires in the plant is addressed in FNP-0-EIP-13; the Gaitronics communication system is available to contact the control room. Furthermore, fire brigade equipment is maintained as described in FNP-O-EIP-16.

Fire brigade organization and training, practice drills, and records are covered by training. In addition, FSAR sections 9B.2.3 and 9B.2.4 provide a brief description of the fire brigade and fire brigade training. The fire brigade is composed of five trained personnel on each shift, with a shift foreman as the brigade leader, two systems operators, a chemistry technician, and a plant guard. The fire brigade has at its disposal protective clothing, respiratory equipment, emergency communications equipment (Gaitronics, portable radios, and sound-powered telephone systems), portable lighting, portable ventilation systems, and portable fire extinguishers.

Each person assigned to the fire brigade is trained to perform assigned duties as a fire brigade member. Training is presented prior to formal assignment to the fire brigade.

This training reviews the plant firefighting plan, firefighting strategies and procedures, and identification of each member's responsibilities. Training also identifies typical fire hazards and types of fires that may occur at the plant, and provides the identification and location of firefighting equipment and familiarization with the plant layout. In addition, the proper use of available firefighting equipment, the correct method of fighting different types of fires, and the proper uses of communication, lighting, ventilation, and emergency breathing equipment are also covered in the training.

Periodic drills are performed to evaluate the brigade's effectiveness; time to respond; and selection, placement, and use of fixed and portable equipment. Drills are conducted on all shifts and are not normally announced. The drills are conducted quarterly for each brigade. The fire drills, which consist of different scenarios covering various plant areas, simulate the size and types of fires that could reasonably be expected in different areas with and without automatic suppression system operation. The drills verify the adequacy of plant firefighting equipment and the ability of the fire brigade chief to develop and implement firefighting strategies based on his training and experience. The validity of fire zone data sheets is also tested during these fire drills.

Furthermore, each member is required to participate in a yearly practice session where actual fires, similar to those which may occur in the plant, are extinguished, and emergency breathing apparatus is used. Records are maintained for each member, demonstrating that the minimum level of training and refresher training has been provided. EPRI TR-100370, section 4, discusses the effects of smoke on equipment and human performance and the effectiveness of the operator action in the event of a fire.

As documented in FSAR section 9B.3, FNP has been reviewed to determine that the total fire protection program provides adequate assurance that a fire will not negate the SSD of the plant, will not significantly increase the risk of radioactive release to the environment, and will not cause undue risk to the health and *safety* of the public.

In the event of a MCR fire that requires evacuation, the alternative shutdown capability for the cable-spreading room is sufficient to achieve and maintain cold shutdown. Furthermore, the functional requirements for hot standby and cold shutdown due to a fire in the MCR are identical to those required for a fire in the cable-spreading room, and are covered by 10 CFR 50, Appendix R, Fire Protection Program for Operating Nuclear Power Plants, Alternative Shutdown Capability (A-350970).

FSAR section 9B.3 documents that self-contained breathing apparatus are available to the operators so that evacuation is not required because of smoke conditions. As stated in FSAR section 9B.4.1.27, at least eight self-contained breathing masks are located in the MCR, and at least three masks are in the access control area for use by control room, fire brigade, and damage control personnel.

3.0 ASME/ANS RA-Sa-2009 Self-assessment

Table 4-2.11-2(a) Supporting Requirements (SR) for HLR-SF-A				
Index No. SF-A	Capability Category I	Capability Category II	Capability Category III	Self-Assess
SF-A1	For those physical analysis units within the Fire PRA global analysis boundary, *(a)* LOOK for fire ignition source scenarios that might arise as the result of an earthquake that would be unique from those postulated during the general analysis of each physical analysis unit, *and* *(b)* PROVIDE a qualitative assessment of the potential risk significance of any unique fire ignition source scenarios identified			Meets: I/II/III Section 2.1
SF-A2	For those physical analysis units within the Fire PRA global plant analysis boundary, *(a)* REVIEW installed fire detection and suppression systems and provide a qualitative assessment of the potential for either failure (e.g., rupture or unavailability) or spurious operation during an earthquake, *and* *(b)* ASSESS the potential impact of system rupture or spurious operation on postearthquake plant response including the potential for flooding relative to water-based fire suppression systems, loss of habitability for gaseous suppression systems, and the potential for diversion of suppressants from areas where they might be needed for those fire suppression systems associated with a common suppressant supply			Meets: I/II/III Section 2.2 and 2.3
SF-A3	ASSESS the potential for common-cause failure of multiple fire suppression systems due to the seismically induced failure of supporting systems such as fire pumps, fire water storage tanks, yard mains, gaseous suppression storage tanks, or building standpipes.			Meets: I/II/III Section 2.2
SF-A4	REVIEW plant seismic response procedures *and* Qualitatively ASSESS the potential that a seismically induced fire, or the spurious operation of fire suppression systems, might compromise postearthquake plant response.			Meets: I/II/III Section 2.2, 2.3 and 2.4
SF-A5	REVIEW *(a)* plant fire brigade training procedures and ASSESS the extent to which training has prepared firefighting personnel to respond to potential fire alarms and fires in the wake of an earthquake *and* *(b)* the storage and placement of firefighting support equipment and fire brigade access routes, *and* *(c)* ASSESS the potential that an earthquake might compromise one or more of these features			Meets: I/II/III Section 2.4

Table 4-2.11-3(b) Supporting Requirements (SR) for HLR-SF-B				
Index No. SF-B	Capability Category I	Capability Category II	Capability Category III	Self-Assess
SF-B1	DOCUMENT the results of the seismic/fire interaction analysis, including the results and insights gained from any unique fire scenarios that were identified, in a manner that facilitates Fire PRA applications, upgrades, and peer review.			Meets: I/II/III All Sections

4.0 REFERENCES

1. Electric Power Research Institute (EPRI) and United States Nuclear Regulatory Commission Research Branch (USNRC-RES), *Fire PRA Methodology for Nuclear Power Facilities*, EPRI TR-1011089 - NUREG/CR-6850, August 2005.
2. Joseph M. Farley Nuclear Plant Unit 1 and Unit 2 Individual Plant Examination of External Events, June 28, 1995.
3. SNC, Unresolved Safety Issue A-46 Summary Report, June 1995.
4. USNRC, NUREG-1407, "Procedural and Submittal Guidance for the Individual Plant Examination of External Events (IPEEE) for Severe Accident Vulnerabilities, Final Report," Washington, D. C., June 1991.
5. Seismic Qualification Utility Group, "Generic Implementation Procedure (GIP) for Seismic Verification of Nuclear Plant Equipment," Revision 2, February 14, 1992.
6. Electric Power Research Institute (EPRI), EPRI NP-6041-SL, "A Methodology for Assessment of Nuclear Power Plant Seismic Margin," (Revision 1), Palo Alto, Ca, August 1991.