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Seismic Screening Criteria  
for  
Assessing Potential Fuel Pool Vulnerabilities  
at  
Decommissioning Plants

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Revision 1

12/13/99

## Background

To increase the efficiency and effectiveness of decommissioning regulations, the NRC staff has engaged in rulemaking activities that would reduce the need to routinely process exemptions once a plant is permanently shut down. With this goal in mind, members of the NRC staff, industry representatives and other stakeholders held a two-day workshop on risk related spent fuel pool accidents at decommissioning plants.

At this workshop, based upon presentations by the NRC staff (Goutam Bagchi et al.) and the nuclear industry (T. O'Hara - DE&S), it was concluded that a large seismic event (in the range of three times the design level earthquake) would represent a risk of exceeding the structural capacity of the spent fuel pool and thus potentially result in draining the pool.

Although the methodologies presented by the NRC staff and the industry differed somewhat, they both concluded that, in general, spent fuel pools possess substantial capacity beyond their design basis but that variations in seismic capacity existed due to plant specific details (i.e. "Differences in seismic capacity due to spent fuel location and other details.").

The consensus was that the risk was low enough that precise quantification was not necessary to support exemption requests but that this needed to be confirmed on a plant specific basis with deterministic criteria. It was recommended that a simple spent fuel pool (SFP) vulnerability check list be developed to provide additional assurance that no beyond-design-basis seismic structural vulnerabilities exist at decommissioning plants. A draft seismic screening checklist was provided to the Staff by NEI in August 1999. Comments on this draft were discussed during a conference call held on December 7, 1999 and the following draft screening checklist has been revised to address the issues raised..

## Spent Fuel Pool Seismic Vulnerability Check List

### Purpose of Checklist

As discussed briefly in the "Background" section, the purpose of this checklist is to identify and evaluate specific seismic characteristics which might result in a specific spent fuel pool from not being capable of withstanding, without catastrophic failure, a beyond-design-basis seismic event equal in magnitude to approximately three times its design basis. Completion of the requirements will be performed by a qualified seismic engineer. This effort will include a thorough SFP walkdown and a review of appropriate SFP design drawings.

### **DRAFT CHECKLIST**

#### **Item 1:**

Requirement:            Identify Preexisting Concrete and Liner Plate Degradation

Basis: A detailed review of plant records concerning spent fuel pool concrete and liner plate degradation should be performed and supplemented by a detailed walkdown of the accessible portions of the spent fuel pool concrete and liner plate. The purpose of the records review and visual inspection activities is to accurately assess the material condition of the SFP concrete and liner in order to assure that these existing material conditions are properly factored into the remaining seismic screening assessments.

Design Feature:        The material condition of the SFP concrete and liner, based upon the records review and the walkdown inspection, will be documented and used as an engineering input to the following seismic screening assessments.

#### **Item 2:**

**Requirement: Assure Adequate Ductility of Shear Wall Structures**

**Basis:** The expert panel involved with the development of Reference 1 concluded that, "For the Category 1 structures which comply with the requirements of either ACI 318-71 or ACI 349-76 or later building codes and are designed for an SSE of at least 0.1g pga, as long as they do not have any special problems as discussed below, the HCLPF capacity is at least 0.5g pga." This conclusion was based upon the assumption that the shear wall structure will respond in a ductile manner. The "special problems" cited deal with individual plant details which could prevent a particular plant from responding in the required ductile fashion. Examples cited in Reference 1 included an embedded structural steel frame in a common shear wall at the Zion plant (which was assumed to fail in brittle manner due to a potential shear failure of the attached shear studs) and large openings in a "crib

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house" roof (also at the Zion plant) which could interrupt the continuity of the structural slab.

Other examples which could impact the ductility of the spent fuel pool structure include large openings which are not adequately reinforced or reinforcing bars that are not sufficiently embedded to prevent a bond failure before the yield capacity of the steel is reached.

**Design Feature:** This design feature requirement will be documented based on a review of drawings and a SFP walkdown.

**Item 3:****Requirement: Assure Design adequacy of Diaphragms (including roofs)**

**Basis:** In the design of many nuclear power plants, the seismic design of roof and floor diaphragms has often not received the same level of attention as have the shear walls of the structures. Major cutouts for hatches or for pipe and electrical chases may pose special problems for diaphragms. Since more equipment tends to be anchored to the diaphragm compared to shear walls, moderate amounts of damage may be more critical for the diaphragm compared to the same amount of damage in a wall.

Based upon the guidance provided in Reference 1, diaphragms for Category I structures designed for a SSE of 0.1g or greater do not require an explicit evaluation provided that: (1) the diaphragm loads were developed using dynamic analysis methods; (2) they comply with the ductility detailing requirements of ACI 318-71 or ACI 349-76 or later editions. Diaphragms which do not comply with the above ductility detailing or which did not have loads explicitly calculated using dynamic analysis should be evaluated for a beyond-design-basis seismic event in the 0.45-0.5g pga range.

**Design Feature:** This design feature requirement will be documented based on a review of drawings and a SFP walkdown.

**Item 4:****Requirement: Verify the Adequacy of the SFP Walls and Floor Slab to Resist Out-of-Plane Shear and Flexural Loads**

**Basis:** For PWR pools that are fully or partially embedded, an earthquake motion that could

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cause a catastrophic out-of-plane shear or flexural failure is very high and is not a credible event. For BWR pools (and PWR pools that are not at least partially embedded), the seismic capacity is likely to be somewhat less and the potential for out-of-plane shear and/or flexural wall or base slab failure, at beyond-design-basis seismic loadings, is possible.

A structural assessment of the pool walls and floor slab out-of plane shear and flexural capabilities should be performed and compared to the realistic loads expected to be generated by a seismic event equal to approximately three times the site SSE. This assessment should include dead loads resulting from the masses of the pool water and racks, seismic inertial forces, sloshing effects and any significant impact forces.

Credit for out-of-plane shear or flexural ductility should not be taken unless the reinforcement associated with each failure mode can be shown to meet the ACI 318-71 or ACI 349-49 requirements.

Design Feature: Compliance with this design feature will be documented based upon a review of drawings (in the case of embedded or partially embedded PWR pools) or based upon a review of drawings coupled with the specified beyond-design-basis shear and flexural calculations outlined above.

**Item 5:****Requirement: Verify the Adequacy of Structural Steel (and Concrete) Frame Construction**

**Basis:** At a number of older nuclear power plants, the walls and roof above the top of the spent fuel pool are constructed of structural steel. These steel frames were generally designed to resist hurricane and tornado wind loads which exceeded the anticipated design basis seismic loads. A review of these steel (or possibly concrete) framed structures should be performed to assure that they can resist the seismic forces resulting from a beyond-design-basis seismic event in the 0.45-0.5g pga range. Such a review of steel structures should concentrate on structural detailing at connections. Similarly, concrete frame reviews should concentrate on the adequacy of the reinforcement detailing and embedment.

Failure of the structural steel superstructure should be evaluated for its potential impact on the ability of the spent fuel pool to continue to successfully maintain its water inventory for cooling and shielding of the spent fuel.

**Design Feature:** This design feature requirement will be documented based on a review of drawings and a SFP walkdown.

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### Item 6:

#### **Requirement: Verify the Adequacy of Spent Fuel Pool Penetrations**

**Basis:** The seismic and structural adequacy of any spent fuel pool (SFP) penetrations whose failure could result in the draining or syphoning of the SFP must be evaluated for the forces and displacements resulting from a beyond-design-basis seismic event in the 0.45-0.5g pga range. Specific examples include SFP gates and gate seals and low elevation SFP penetrations, such as, the fuel transfer chute/tube and possibly piping associated with the SFP cooling system. Failures of any penetrations which could lead to draining or syphoning of the SFP should be considered.

**Design Feature:** This design feature requirement will be documented based on a review of drawings and a SFP walkdown.

### Item 7:

#### **Requirement: Evaluate the Potential for Impacts with Adjacent Structures**

**Basis:** Structure-to-structure impact may become important for earthquakes significantly above the SSE, particularly for soil sites. Structures are usually conservatively designed with rattle space sufficient to preclude impact at the SSE level but there are no set standards for margins above the SSE. In most cases, impact is not a serious problem but, given the potential for impact, the consequences should be addressed. For impacts at earthquake levels below 0.5g pga, the most probable damage includes the potential for electrical equipment malfunction and for local structural damage. As cited previously, these levels of damage may be found to be acceptable or to result in the loss of SFP support equipment. The major focus of this impact review is to assure that the structure-to-structure impact does not result in the inability of the SFP to maintain its water inventory.

**Design Feature:** This design feature requirement will be documented based on a review of drawings and a SFP walkdown.

### Item 8:

#### **Requirement: Evaluate the Potential for Dropped Loads**

**Basis:** A beyond-design-basis seismic event in the 0.45-0.5g pga range has the potential to cause

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the structural collapse of masonry walls and/or equipment supports systems. If these secondary structural failures could result in the accidental dropping of heavy loads which are always present (i.e. not loads associated with cask movements) into the SFP, then the consequences of these drops must be considered. As in previous evaluations, the focus of the drop consequence analyses should consider the possibility of draining the SFP. Additionally, the evaluation should evaluate the consequences of any resulting damage to the spent fuel or to the spent fuel storage racks.

**Design Feature:** This design feature requirement will be documented based on a review of drawings and a SFP walkdown.

**Item 9:**

**Requirement:** **Evaluation of Other Failure Modes**

**Basis** Experienced seismic engineers should review the geotechnical and structural design details for the specific site and assure that there are not any design vulnerabilities which will not be adequately addressed by the review areas listed above. Soil-related failure modes including liquefaction and slope instability should be screened by the approaches outlined in Reference 1 (Section 7 & Appendix C).

**Design Feature:** This design feature requirement will be documented based on a review of drawings and a SFP walkdown.

**Item 10:** **Potential Mitigation Measures**

Although beyond the scope of this seismic screening checklist, the following potential mitigation measures may be considered in the event that the requirements of the seismic screening checklist are not met at a particular plant.

a.) Delay requesting the licensing waivers (E-Plan, insurance, etc.) until the plant specific danger of a "zirc-fire" is no longer a credible concern.

b.) Design and install structural plant modifications to correct/address the identified areas of non-compliance with the checklist. (It must be acknowledged that this option may not be practical for significant seismic failure concerns.)

c.) Perform plant-specific seismic hazard analyses to demonstrate that the seismic risk associated with a catastrophic failure of the pool is at an acceptable level. (The exact "acceptable" risk level has not been precisely quantified but is believed to be in the range of 1.0E-06.)

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### **Item 11: Required Documentation**

A simple report describing the results of the seismic engineer's walkdown and drawing review findings is judged to provide sufficient documentation to rule out a beyond-design-basis seismic event as a significant risk contributor to a decommissioned nuclear power plant.

### **References:**

1. "A Methodology for Assessment of Nuclear Power Plant Seismic Margin Revision 1)," (EPRI NP-6041-SL), August 1991