Response to Questions Concerning Spent Fuel Pool Seismic-Induced Failure Modes and Locations and the Expected Level of Collateral Damage

by
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1. Introduction

This brief report responds to the following two questions from the NRC Staff:

1) What are the most likely spent fuel pool failure modes and locations?

2) What is the expected level of collateral damage given a seismic event necessary to fail the spent fuel pool?

The following responses are based upon my judgement without performing any calculations.

2. Most Likely Spent Fuel Pool Failure Modes and Locations

Ref. 1 presents seismic fragility estimates for the Vermont Yankee (BWR) and Robinson (PWR) spent fuel pools. These two fragility estimates are the only spent fuel pool fragility estimates that I have seen. Therefore, my judgement is heavily based on the results presented in Ref. 1.

For Vermont Yankee (BWR), Ref. 1 states that the critical failure mode for the gross structural failure of the pool is an out-of-plane shear failure of the pool floor slab. With this failure mode, the liner will be breached and a large crack will develop through the concrete floor slab within a distance equal to the floor slab thickness from the pool walls. Possibly the entire floor will drop out, but I think that such a gross failure is unlikely. However, the concrete crack will be sufficiently large that the water in the pool will quickly drain out.

Although not reported as the critical failure mode in Ref. 1, my judgement is that for BWR pools, it is at least equally likely that the critical failure mode will be an out-of-plane shear failure of one or more of the pool walls. With this failure mode, the liner will be breached and a major concrete crack will form along the length of the wall within a wall thickness distance from the top of the floor slab.

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Water will quickly drain out of the pool. However, as much as 4-feet of water depth will likely remain within the pool.

For Robinson (PWR), Ref. 1 states that the critical failure mode is an out-of-plane bending failure of the East wall. With this failure mode, the liner will be breached and the concrete will become rubbled over a zone equal to the wall thickness at the base of the wall and along the two sides (ends) of the wall. The outward flow of water is likely to be somewhat slower than for a shear crack, but is still expected to be rapid. Probably less water will be retained in the pool than for the case of a shear crack through the wall, and more water will be retained than for the case of a shear crack through the pool floor.

Although not reported as the critical failure mode in Ref. 1, I believe that either of the two shear failure modes reported above for a BWR could also be the critical failure mode for some PWR pools.

Lastly, for stronger spent fuel pools with greater out-of-plane flexure and shear capacities, an in-plane shear failure mode for one or more of the pool walls could control. I suspect this will be the case for particularly some PWR pools. With this failure mode, the liner will be breached and the concrete wall will be cracked in a diagonal X pattern of cracking from near the base of the wall at the edges to near the top of the wall at the opposite edges. The pool will empty to near the base of the wall with probably some small amount of water being retained in the pool.

No matter which of these failure modes occur, drainage of the pool is expected to be fairly rapid. A small, but uncertain, amount of water is likely to remain in the pool with post-seismic-failure water depths ranging from essentially zero depth to about 4-feet of depth depending upon the critical failure mode.

3. Expected Level of Collateral Damage

The seismic capacity of spent fuel pools is high. For spent fuel pools that have successfully passed the NEI/NRC seismic walkdown procedure, I believe the spent fuel pool will have at least about the following seismic fragility capacities:

Spent Fuel Pool

$$C_{1\%} = 0.5g \text{ PGA}$$
$$C_{10\%} = 0.75g \text{ PGA} \qquad (1)$$
$$C_{50\%} = 1.25g \text{ PGA}$$

where $C_{1\%}$, $C_{10\%}$, and $C_{50\%}$ are the 1%, 10%, and 50% non-exceedance probability

(NEP) peak ground acceleration capacities.

For the Central and Eastern U.S. (CEUS), I estimate the following seismic fragilities:

Loss of Offsite Power

$$C_{1\%} = 0.10g \text{ PGA}$$
$$C_{10\%} = 0.18g \text{ PGA} \quad (2)$$
$$C_{50\%} = 0.35g \text{ PGA}$$

Loss of Even Temporary Safe Usability of Well Designed Buildings and Bridges

$$C_{1\%} = 0.20g \text{ PGA}$$
$$C_{10\%} = 0.35g \text{ PGA} \quad (3)$$
$$C_{50\%} = 0.75g \text{ PGA}$$

Thus, for a 0.5 PGA scenario ground motion, I would expect less than about a 1% chance of the spent fuel pool failing to hold water, about a 70 to 75% chance that offsite power to the station is lost, and about 20 to 25% of the well designed surrounding buildings (housing communication systems) and bridges being unsafe to use even temporarily. By "well designed", I mean the building or bridge has some form of lateral load carrying system, but does not have nuclear plant or California levels of seismic design. Many CEUS buildings and bridges will have lesser seismic capacity than does this "well-designed" category, and a few might be better. Therefore, over the entire population of nearby buildings and bridges, I would expect more than 20 to 25% would be unsafe for even temporary use.

For a 0.75g PGA scenario ground motion, I would expect less than about a 10% chance of the spent fuel pool failing, about a 90% chance that offsite power is lost, and more than about 50% of the CEUS buildings and bridges being unsafe for even temporary use. At this ground motion level which is within the region of ground motions that dominate the estimated seismic risk of spent fuel pool failures, sufficient power, buildings housing communication systems and emergency services, and bridges will be out-of-service that emergency responses will most likely have to be ad-hoc. Specifically, for ground motion levels that correspond to spent fuel pool failure, within at least 10 miles of the plant I would expect power to have been lost and more than about 50% of the CEUS bridges and buildings (including those housing communication systems and emergency response equipment) being unsafe for even temporary use.

4. Reference

1. *Seismic Failure and Cask Drop Analyses of the Spent Fuel Pools at Two Representative Nuclear Power Plants,* NUREG/CR-5176, Prepared for

Nuclear Regulatory Commission, January 1989