From: Nilesh Chokshi RES
To: George Hubbard, Goutam Bagchi NRR
Date: Fri, Aug 11, 2000 1:34 PM
Subject: Re: Spent Fuel Pool Decommissioning: Seismic Screening

Goutam/George,

I am attaching a file with my comments (strikeout and redline) on Goutam's draft . In few places I have embedded questions we need to discuss. I think we will need one more iteration. I would like to have Bob Kennedy look at it also before we finalize it. We are working on Bob's contract so that he can review this and attend August 23rd meeting. It would be very useful if we can include figures and data to enhance our discussion on uncertainties.

Nilesh

CC: David Diec, Diane Jackson, Gareth Parry, Glenn Kelly, John Hannon, Mark Rubin, Michael Mayfield, Richard Barrett, Robert Rothman(...)

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Outline- White Paper on Seismic Risk of Spent Fuel Pool in Decommissioning

Current Approach:

Spent fuel pool structures at nuclear power reactor facilities are constructed with thick reinforced concrete walls and slabs from radiation shielding considerations. This construction provides the pool structures considerable strength reserve for resisting seismic loads much beyond its design basis seismic loading. The study of the failure probability of spent fuel pools was conducted by Dr. Robert Kennedy utilizing the two currently available seismic hazard estimates, one by the Lawrence Livermore National Laboratory (LLNL) and the other by the Electric Power Research Institute (EPRI). The result of the Kennedy study shows that the seismic probability of failure of spent fuel pools generally fall below 1.3XE-6 using the LLNL hazard, except for about 9 sites where the probability of failure is somewhat higher. This was a generic study using a capacity assumption of 1.2 g spectral acceleration. The capacity at individual spent fuel pools could be higher in many cases; however, in some cases of elevated pools this margin can be close to one ~~and somewhat smaller in cases where out of plane shear failure can be a concern~~. In order to determine a criteria for generically eliminating the concern for seismic failure, the NRC staff proposed an approach based on a physical verification of the pool structure followed by a confirmation of structural capacity at the levels of 2XSSE and 3XSSE for the west and east coast sites respectively. This was a bounding approach and the staff was very confident that the plants screened out by this approach would have a very low failure probability and in a risk informed sense, the seismic failure likelihood for these plants can be ignored as being too small. Although, from a risk point of view the seismic failure probability was assumed to be 1.3E-6, keeping in mind that there is a factor of conservatism in the capacity of pool structures.

From the seismic hazard stand point, both the LLNL and the EPRI estimates are equally credible estimates and there divergence in individual site results stem from the large uncertainty in the ground motion modeling. The modeling uncertainty in seismic hazard estimates is large and dominate uncertainties in the seismic risk estimates. These large uncertainties make it difficult to compare point estimates of seismic risk with the point estimates of risks from other initiator. In any comparison it is important to consider the full distribution, sources of uncertainties, and nature of uncertainties. ~~swell known and they are so large that seismic risk estimates are generally not compared with risk from internal events and are used in a relative sense.~~

Key Assumptions:

1. ~~Site specific SSE values generally correlate with the site seismic hazard and can be used as a basis for a bounding set of criteria~~. *(Note: Goutam, we need to discuss. I am not sure what are the implications.)*
2. LLNL and EPRI hazard estimates are equally valid. LLNL results being generally higher represent upper bound of estimates ~~more conservative, should be used for consideration in risk informed decisions~~.
3. High confidence ~~in~~ low probability of failure (HCLPF) capacity of spent fuel pool ~~capacity can be represented generically by~~ is 1.2 g spectral acceleration (~ 0.5g peak ground acceleration) ~~at a high confidence in low probability of failure~~. Generic fragility uncertainty estimates are applicable to all plants. *(Note; Goutam, let us talk briefly about this.)*

4. A physical verification of the structural integrity of spent fuel pools, confirmation of structural strength based verification of construction drawings, affirmation of no ongoing age related degradation and verification that there are no sources of seismic interaction between pool structures and the superstructure are to be conducted through the use of a seismic check list.

Sources of Conservatism:

1. ~~For some eastern US sites, the SSE frequency is very low or does not correlate to the seismic hazard estimate.~~
2. Although the 1993 LLNL hazard estimates correlated well with the EPRI results at the SSE levels and both methods are consistent in the relative sense (i.e., the ranking of sites from to low hazard is almost identical), the LLNL hazard estimates ~~are significantly more conservative than the EPRI estimates~~ for earthquakes several times larger than the SSE levels are significantly higher than EPRI estimates.
3. The structural capacity of spent fuel pools is set at a relatively low value that can be readily verified through a peer reviewed data base.

It is important to note that the most easily quantifiable source of conservatism - the plant capacities - will require detailed plant-specific analysis. As noted earlier, the benefits are non-uniform. It is very likely that most PWRs will show much larger margin with relatively little less effort. Benefits to BWRs will greatly depend on the specific configurations.

Reduction of uncertainties in the hazard estimates (see additional discussions below), and hence conservatism in the mean estimates, is a significant plant-specific undertaking requiring incorporation of the recent ground motion models and may prove to be contentious at potential hearings.

Sources of Uncertainty

1. The primary source of uncertainty is in the ground motion estimates at very low frequencies in the 1XE-5 to 1XE-6 range. These uncertainties come from seismogenic sources boundaries and the assumptions of ground motion attenuation. NEI study shows that a change in sigma, the attenuation uncertainty, from 0.4 to 0.5 changes the probability of exceeding 1000 cm/sec ^{2}, an acceleration value in the range of interest for structural failures, by a factor of about 100.
2. New ground motion modeling is likely to reduce uncertainty and reduce level of motion at large return periods.
3. Plant specific fragility uncertainties could be smaller in some cases ~~capacity values are likely to be higher.~~

Quantification of Uncertainty

1. Ground motion modeling has the largest source of uncertainty. There are two effects here, one is the site specific uncertainty in the hazard estimate ~~where a factor of 3 is in the noise range,~~ and the other results from the bounding effect In a bounding approach a large number of sites are well below the screening value, because of this approach a margin exists for certain specific sites, but the factor is not quantifiable.
2. The joint NRC and DOE study on ground motion that was recently completed can be used to better estimate the seismic hazard. It is expected that in a large majority of

cases, the frequency of large ground motions will come down. This factor is not readily quantifiable.

3. In the spent fuel pool fragility evaluation, the deep box shape of the pool needs to be taken into account. The available fragility evaluation has not considered the ultimate failure mode. Near the lower part of the pool membrane stretching would be the primary mode of load transfer and in the upper part of the pool the load would be carried by out of plane shear. Since the out of plane shear in the upper part would be quite a bit less, there will be some margin that is currently not recognized. In the absence of a detailed finite element analysis of the pool structures in three dimension, it is the staff judgement that the additional margin is in the order of a factor of 2.
4. The overall factor of conservatism is judged to be about a factor of 5.

Proposed approach

Considering the ACRS comment, detailed NEI comments and reviewing the factors of conservatism as discussed above, the staff finds that in Table 3 of Dr. Kennedy's report the probability of failure of 4.5XE-6 provides a convenient line of demarcation between sites with low probability of failure and four sites with relatively high probability of failure. This also means that the seismic check list can be used with a 0.5 g capacity screening. Looking at the NEI letter of November 2, 1999 there is a figure which shows a 1XE-6 per year failure probability line that covers all but five sites. These two approaches produce essentially the same ranking of plant failure probability. Although the figures of merit in the two cases are different, when used in relative sense they yield the same result. Given the factors of conservatism, one can argue that the seismic screening of plants at 1.2 g spectral acceleration provides assurance of a low probability of failure due to earthquakes in the order of 1XE-6 per year and a physical verification of structural adequacy of the pools.

The end result of the proposed approach is that three eastern plants may have to do additional calculations to estimate capacities beyond the walkdown and checklist. Note that, no matter what approach is adopted, the confirmation and verification of no vulnerabilities through walkdown and checklist will be necessary. This approach is the most efficient approach if the seismic risk in order of 10E-6 is treated as other low risk initiators. Demonstration of seismic risk much below this value will require significant effort and may not be achievable in all cases.

Decision-Making Framework for Seismic Risk:

The staff intends to display separate results for both LLNL and EPRI as indicators of range of results and also to display mean and median (may require additional calculations) results to high light uncertainties, sources of uncertainties, and to provide a perspective on seismic risk when compared to other initiators.

Conclusions and Recommendations:

Using either the LLNL or the EPRI/NEI results, the plant risk ranking remains essentially the same and the proposed approach ensures, through the seismic check list and walkdown, seismic capacity and low risk. Only three Eastern US plants may require additional analysis. Refinements will not lead to a different conclusion as the results will be very plant specific and factors greater than 5 (for example) will be difficult to obtain because of hazard driven uncertainties.

Considering the above factors (i.e., knowing the bounding range, sources of uncertainties, and nature of uncertainties), the most useful index for risk-informed decision is the capacity measure, that is, if a plant demonstrates or confirms that the plant HCLPF is greater than 1.2g spectral (~0.5g peak ground acceleration), the seismic risk is acceptably low and should be treated in the same fashion as other low-risk initiators. The seismic risk should not be a determinant of requirements for EP, insurance, etc.