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General Comment

See attached file(s)

Attachments

EPRI Comments on NRC Draft SFPS_July 2013

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Add= D. Algama (dra)

July 31, 2013

Cindy Bladey
Chief, Rules, Announcements, and Directives Branch (RADB)
Office of Administration
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Subject: Comments on Draft Report: Consequence Study of a Beyond-Design-Basis Earthquake Affecting the Spent Fuel Pool for a U.S. Mark I Boiling Water Reactor

Dear Ms. Bladey:

Thank you for the opportunity to review the subject draft report. The draft study is a detailed examination of the consequences of a beyond-design-basis earthquake on the spent fuel pool (SFP) of a typical BWR-4 reactor, Mark I containment. Within the scope of this study, the authors have applied many state-of-the-art methods and have clearly identified assumptions and limitations associated with the analysis. In addition, the results of the draft study are consistent with previous studies (including those reported in NUREG/CR-6451 and in NUREG-1738) and illustrate that several characteristics may limit the risk of fuel damage in a SFP. These characteristics include:

- The robustness of the SFP structure;
- The relatively small heat load in the SFP during most of the operating cycle, which limits the potential for overheating of the fuel;
- Storage patterns that can further minimize the potential for overheating of the fuel; and
- The availability of mitigating actions, including spraying into the pool, that can be effective in keeping the stored fuel cool.

While EPRI believes that the study advances understanding of potential beyond basis accidents that can affect spent fuel pools, it would appear that there are opportunities for further improvement in the analyses. In the attachment we have provided a summary of potential clarifications, additions and refinements that would contribute to this improvement. Again, thank you for the opportunity to comment.

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Sincerely,

Stuart R. Lewis
Program Manager
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RSM-080113-007

Enclosure

EPRI Comments on the Draft NRC Report "Consequence Study of a Beyond-Design-Basis Earthquake Affecting the Spent Fuel Pool for a U.S. Mark I Boiling Water Reactor"

The NRC Spent Fuel Pool Study (SFPS) is a detailed examination of the consequences of a beyond-design-basis earthquake scenario on the spent fuel pool (SFP) of a typical BWR-4 reactor, Mark I containment. Within the scope of this study, the authors have applied many state-of-the-art methods and have clearly identified assumptions and limitations associated with the analysis.

The SFPS results illustrate, more fully than has been done previously, that several characteristics may reduce the risk of fuel damage in a SFP. These include:

- The robustness of the SFP structure itself,
- The fact that during most of the fuel cycle, the heat load in the SFP is small enough to make overheating extremely unlikely when air cooling can be achieved,
- The potential that certain storage patterns may further minimize the potential for overheating of stored fuel, and
- Mitigating actions, including spraying into the pool, that may be effective in keeping the stored fuel cool.

The comments provided below focus on elements of the analysis that would benefit from additional clarification or refinement or that could further improve the usefulness of the analysis.

1. Overall scope. The SFPS is a consequences analysis as opposed to a full risk assessment. This is highlighted and acknowledged in the title as well as several times throughout the report. A more comprehensive probabilistic evaluation, while more resource intensive, would provide greater refinement and insight and increase the usefulness of the study, such as in risk-informed regulatory activities.

2. Interactions between reactor and SFP. The SFPS acknowledges the potential for interactions between the reactor and the spent fuel pool, and identifies such interactions in Section 2.2. These interactions are not, however, evaluated within the scope of the study. This decoupling of the SFP from the reactor affects several parameters including the potential for hydrogen from a reactor accident to collect in the SFP area, with the possibility of combustion; the timing of assumed operator actions; and the timing of the general emergency order (potential to affect evacuation). Additional discussion or basis would be helpful.

3. Spray cooling. Several assumptions associated with spray cooling made in the SFPS could benefit from further discussion or basis.

   a. The report assumes a uniform spray flux of water over the top of the SFP. Depending on timing and locations at which operator actions would need to be taken (e.g., proximity to pool and radiation fields), it may be difficult to align the spray. It could also be difficult to achieve 100% coverage if debris has blocked the top of some fuel assemblies.

b. The option to spray into the SFP from outside the Reactor Building is possible if the refueling floor is open to the environment. Depending on the size of the assumed opening, this option could limit the ability to achieve full spray coverage of the pool, but might be more likely to result in atmospheric scrubbing of the radionuclides.

c. Spraying into the refueling floor and spent fuel pool from an external position creates the potential for direct release to the environment that is not currently included. Any operator actions to ventilate the building are considered should be considered in this context as well.

d. The report indicates that "for PBAPS, the capacities of the available equipment are somewhat higher. The use of ... 200 gpm here attempts to account for uncertainties in the ... spray that goes outside the boundary of the pool". However, it is not clear whether this particular conservatism could balance the potential lack of full spray effectiveness noted above.

4. Air cooling. Several assumptions associated with air cooling made in the SFPS could benefit from further discussion, basis, or more detailed treatment.

   a. Air cooling of the assemblies is dependent upon having clear channels for air flow. Debris from the Reactor Building superstructure or miscellaneous equipment on the refueling floor could conceivably fall into the pool, potentially damaging the liner or impeding local air flow in the SFP channels. The analysis does not consider debris interaction with the SFP resulting either from a large seismic event or from a hydrogen combustion event (see Section 1, Table 3 for technical basis). Additional technical justification or a sensitivity analysis may be desirable. We do note that experience from recent large seismic events, including Kashiwazaki-Kariwa 2007, Fukushima Dai-ichi, Fukushima Daini, Onagawa, and North Anna, indicates little or no debris generation and deposition into SFPs due to earthquake itself.

   b. The reports states that "The cool gases leaving the lower regions of the building are not brought into thermal equilibrium with gases above the SFP." (Page 107). This assumption allows for cooler air at the inlet of the fuel. In order to achieve the lower inlet temperatures other actions may be necessary such as opening doors or other access ways to enhance airflow. It may be useful to provide additional justification or sensitivity analysis.

   c. Only the refueling floor is modeled in MELCOR (pp. 105, 107, 108). The equipment shaft from lower Reactor Building elevations is modeled as supplying the air inlet to the SFP. This leads to air temperatures lower than what might be expected. In practice, air ingress into the SFP racks may be limited by the flow area available into the bottom of the pool and the air temperature may be higher than assumed. A sensitivity evaluation may be useful to address this issue.

5. Location and size of SFP breach. Several assumptions associated with the location and size of the SFP breach have been made in the SFPS that could benefit from further discussion or basis.

   a. The crack in the concrete and the tearing of the liner are assumed to occur at the bottom of the SFP. The complete draining of the pool opens the possibility for air cooling, which could be reduced if the leak occurred above the bottom of the fuel. The impact of this assumption can be estimated where fuel assembly inlet flow is delayed, which results in higher fuel temperatures. Further discussion of this particular assumption would be useful.

b. The SFPS acknowledges the large uncertainties for several assumptions associated with location and size of the breach (e.g., finite element modeling of the concrete structure, modeling of the liner strain, modeling of the liner tear and the concrete cracking that would allow leakage flow, and calculation of the friction factor associated with the leakage pathway). Sensitivity calculations could be used to investigate the possible impact of changes to failure location or size. A more probabilistic treatment could produce more refined results.

6. Hydrogen burns. The following comments relate to the assumptions related to hydrogen burn and may merit additional discussion or basis to improve the analysis.

   a. The study predicts cesium releases following hydrogen combustion (approximately 18 hours into the accident) in high density loading but not in low density loading. The difference in outcome is associated with the higher hydrogen concentration in the base case (high density loading).

   b. The MELCOR calculation does not predict that hydrogen combustion will take place on the refueling floor. This result may be influenced by not including the entire reactor building in the model. A sensitivity study that accounts for sufficient oxygen from other parts of the building may produce additional insights.

   c. The SFPS "did not consider hydrogen events originating from a concurrent reactor accident".

   d. Molten core concrete interactions (MCCI) at the bottom of the pool can result in higher release fractions for radionuclides. MCCI can also lead to hydrogen generation. While the sequence is very unlikely, some discussion in the analysis may be warranted.

7. Consequence calculations. The following assumptions related to release, evacuation and contamination may merit additional discussion or basis to improve the analysis.

   a. If the conditions of the reactor do not warrant prompt declaration of a General Emergency (GE) based on the emergency action limits (EALs), then the time to initiate public evacuation could be delayed. Generally, EALs do not include guidelines for declaring a GE for events involving the SFP. For irradiated fuel or SFP events the highest EAL is alert, although a GE is declared by the emergency director.

   b. Early fatalities: The conclusion that there are no calculated early fatalities would benefit from further discussion.

      i. This seems inconsistent with Section 10 (Table 62), which indicates that both NUREG/CR-6451 and NUREG-1738 identified early fatalities from SFP accidents.

      ii. Certain sequences that could take place immediately after refueling can yield early releases, possibly before evacuation can be completed for some plants.

      iii. The magnitude of the release based on sensitivity calculations reported in Section 9.1 is above the magnitude required for early fatalities.

      iv. As discussed above, declaration of a General Emergency (GE) is dependent on the belief that either the reactor is also undergoing a severe accident or that the crew would exercise the judgment to declare a GE based on existing "discretionary" guidance.

      v. The seismic event of 0.71g is assumed not to affect the evacuation and movement of people or impede other protective actions.

vi. Explicit consideration of full-core offload events is not included in the quantified assessment; only refueling events involving the offload of one-third of the core are considered. This is applicable to the majority of cases but may not be valid for all plants and all conditions.

8. Human reliability analysis. The following assumptions related to human reliability analysis merit additional discussion in the study.
   a. The portable equipment for mitigation is assumed to be available and able to be aligned to the SFP despite the potential priority use on the reactor.
   b. The work area to align the equipment is assumed to be accessible despite the draining of the SFP, potential high radiation, and potential loss of building structural integrity.
   c. The applicability of the HRA approach to the conditions of interest in the main report and appendices may merit some additional justification.

9. Insights and conclusions. The report insights contain a number of conclusions that may merit additional discussion or analysis, such as in the form of sensitivity cases to improve the understanding or usability of the final report.
   a. The main report and the associated detailed analysis are a very useful compendium of methods and associated results for the chosen scenario. However, extrapolating the analysis of this single scenario to the risk conclusions drawn in Appendix D introduces large uncertainties and additional assumptions. Explaining and quantifying these uncertainties should be considered.
   b. With respect to insight #3 on p. 246, the "informed expectation" has not been compared against an accepted seismic hazard curve. While the analysis still provides insights, a more traceable seismic hazard would improve the study.
   c. With respect to insight #5 on p. 246, the case is made that the hottest fuel should be stored in 1x8 patterns to minimize the time air cooling would not be effective. This insight was not the focus of the analysis and could benefit from further review or additional discussion to indicate the expected risk impact.
   d. With respect to insight #17 on p. 249, the statement is made that "The risk due to beyond design basis accidents in the spent fuel pool analyzed in this study is sufficiently low that the added costs involved with expediting the movement of spent fuel from the pool to achieve the low-density fuel pool storage alternative are not warranted." This insight is not well supported by the main report because a comprehensive risk assessment has not been performed in the main report. Referencing Appendix D would be needed along with all of the assumptions and inputs used in Appendix D.
   e. To enhance the existing study some additional sensitivity cases and additional investigations may be useful, including:
      i. Sensitivity of hydrogen combustion (MELCOR)
      ii. Sensitivity of 1x fuel assembly pattern (MELCOR)
      iii. Sensitivity to a contiguous(uniform) fuel pattern during an outage (MELCOR/MACCS2
      iv. Sensitivity to concurrent reactor accident (MELCOR) (loss of Reactor Building)
      v. Sensitivity to SFP leakage location and magnitude (MELCOR/MACCS2)

vi. Sensitivity to molten core-concrete interaction (MELCOR/MACCS2)
vii. Sensitivity to radiative heat transfer (MELCOR) (low density case)
viii. Sensitivity to land contamination (MACCS2)
ix. Sensitivity to time truncation (MELCOR/MACCS2)
x. Sensitivity to Reactor Building leakage (MELCOR)
xi. Sensitivity to 50-mile radius assumption (MACCS2)
xii. Sensitivity to scenario duration (>72 hrs)

It seems appropriate that the sensitivities should also address whether these could affect the cost-benefit assessment (e.g., would they affect both configurations in a manner that the differences in consequences apply equally?).