Review of Structural Sections of Draft NUREG on Spent Fuel Transportation Risk Assessment

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Executive Summary

The draft NUREG on Spent Fuel Transportation Risk Assessment (SFTRA) was reviewed with respect to the structural evaluation of representative rail and truck casks. The structural analysis and discussion is adequate and sufficiently broad to support the Risk Assessment. The analyses show that, even in beyond regulatory accidents, the casks will maintain containment and the cask structure will not be so compromised as to make the cask vulnerable to any subsequent fire. Performance of fuel rods at regulatory accident test conditions and at approximately twice the regulatory impact velocity was analyzed. The analysis does not address potential criticality issues associated with deformation of the cask internal structure. Several topics were identified which, if addressed, would strengthen the document. Principal among these are inclusion of general descriptions of the casks, clarified discussion of acceptable O-ring gap, discussion of bolt preload assumptions, and providing a discussion of the results of the analyses in Appendix III. No additional analyses are recommended.

Electronic review mark-ups of Chapter 3 and Appendix III are provided.

Introduction

The Spent Fuel Transportation Risk Assessment is a study of radiological risks associated with transport of spent or used nuclear fuel in commerce. It addresses the performance of typical Type B radioactive material casks to regulatory and beyond regulatory transportation accidents. The evaluation considers fuel of known isotopic composition and burn-up. This part of the review, Chapter 3 and Appendix III, addressed the structural evaluation of the representative packagings.

Scope

The scope of this part of the review of the Draft NUREG was:

> Review the structural evaluation of the casks included in Chapter 3, *Cask Response to Impact Accidents* and Appendix III, *Details of Cask Response to Impact Accidents*. By comparison with the reported performance of similar casks, confirm that the results presented in Chapter 3 and Appendix III are consistent with anticipated impact response for such packagings. Identify any topics that would benefit from additional explanation and, if required, recommend any additional analyses which would be required.

Review

The review included recording comments and suggested editorial changes in the electronic copy of the documents, using the review feature of Microsoft Word. The results of the analyses were compared with analyses of similar casks and with estimates of impact deceleration and impact limiter crushing. The electronic (MS Word) versions of the documents with these comments are attached and provided electronically.

Comments

General Comment: The analysis does not address potential criticality issues associated with deformation of cask internal structure. An explanation of why such an analysis is not needed would strengthen the assessment.

General Comment: Appendix III would be enhanced by providing more detail on the analyses and the results. There are several papers and other studies of these casks, in the open literature, which describe the modeling and results of analysis. A similar description for the regulatory case for each cask, and discussion comparing the effects of higher velocity impacts would be particularly useful. Tables supporting the graphical results with some numerical comparisons could be provided for each cask.

Specific comments have been imbedded in the attached version of the Chapter 3 and Appendix III Word documents using the track changes and comments features of the software.

Comparisons

The results of the analyses reported in Chapter 3 and Appendix III were compared with the results of analyses of similar casks reported in the literature and open access records. The example casks considered here have been analyzed as typical examples of their cask type in other studies. As a result, in addition to comparisons with other rail and truck casks, the available published studies include various analyses of the example designs addressed in this study, HI-STAR 100, NAC-STC and GA-4.

The results of the earlier studies of these representative designs are consistent with the results presented in Chapter 3 and Appendix III of the present draft NUREG for Hypothetical Accident Conditions analyses (References1–4). It is worthy of note that the analyses presented in Chapter 3 and Appendix III are generally based on more refined analyses and are focused on extra-regulatory (high velocity) impacts and impacts with real targets.

Comparison with similar analyses for other large casks shows that the response of the casks is also comparable to that reported in Chapter 3 and Appendix III. In particular, the extent of damage to impact limiters is similar, decelerations are similar and the cask containment boundary closure components are shown to remain elastic, as is the case for the regulatory conditions analyses reported in the present study.

Check Calculations

The information for the Rail-Lead cask was sufficient for an estimate of the impact deceleration and extent of crushing to be made for the regulatory test condition impact. This estimate was based on scaled deformations from the results reported in Appendix III. This simplified evaluation showed that the impact limiters are crushed about 11 inches, radially, resulting in a area of engaged crush material about 80 in. wide. For an impact limiter axial dimension of 44 in. and two impact limiters, the total area of material being crushed was 6900 in^2. Using average crush properties for the redwood of approximately 3100 psi, and a cask mass of 2.5×10^5 lbm, yields a deceleration of approximately 86g, which is comparable to the 76.1g value given in Table III-2 for this case.

A similar estimate of the extent of crushing for the end impact for the Rail-Lead cask confirmed that the redwood was crushed to approximately 70% strain, resulting is significantly higher forces than for the regulatory impact. This result is consistent with the higher impact acceleration reported for the 60 mph and higher cases.

Conclusions and Recommendations

The structural evaluations of the representative casks studied in Chapter 3 and Appendix III show that typical spent fuel casks are able to withstand impacts and maintain containment of their radioactive contents in events much more severe than those required by the Hypothetical Accident Conditions performance requirements of the regulations.

The structural evaluation presented in Chapter 3 and Appendix III is sound and sufficient to show that the casks will maintain containment under the extreme conditions considered.

It is recommended that:

A general description of the casks be provided or that specific reference be made to sections where this information can be found.

The discussion of the acceptability of a 2.5 mm gap at the O-ring seal, noted in the comments above, should be clarified.

References supporting the capability of the inner welded container material to survive high levels of plastic strain should be provided.

The omission of bolt preload should be justified, as noted above.

The crossed rod fuel rod beam-to-beam model should be justified, as noted above.

A discussion of the results of the analysis should be included in the Results sections of Appendix III, as noted above.

References

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Attachments

1. Review Mark-up of Chapter 3, Cask Response to Impact Accidents
2. Review Mark-up of Appendix III, Details of Cask Response to Impact Accidents