NEI

NUCLEAR ENERGY INSTITUTE

Ralph E. Beedle
SENIOR VICE PRESIDENT AND
CHIEF NUCLEAR OFFICER,
NUCLEAR GENERATION

April 26, 2001

Mr. Samuel J. Collins
Director
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Mail Stop O-5 E7
Washington, DC 20555-0001

Dear Mr. Collins:

In the Staff Requirements Memorandum dated December 21, 1999, the Commission's directive to improve regulations for nuclear power plants focused on risk-informing decommissioning regulations. The staff's recently issued NUREG 1738 "Technical Study of Spent Fuel Pool Accident Risk at Decommissioning Nuclear Power Plant," February 2001, was intended to support the decommissioning rulemaking.

The approach taken in the NUREG is not based on a realistic evaluation of risk. In fact, by compounding overly conservative estimates of seismic risk, pool fragility and the probability and magnitude of the postulated fire and its consequent releases, the NUREG provides a worst-case estimate. The result is an overstatement of the risk posed by spent fuel pools and confusion regarding the risk of pools by comparison to the risk of operating plants.

We recommend that the report be withdrawn and reissued after a careful examination of the technical basis and an independent peer review. Detailed recommendations for improving the study are provided in the attached comments.

If I can be of any assistance to you as you review the comments please feel free to contact me, or have your staff contact Lynnette Hendricks at 202 739-8109 or lxh@nei.org.

Sincerely,

Ralph E. Beedle

Enclosure

c: George Apostalokis, Chairman, ACRS

Y6Ø1
add: e-RIDS
RidsNrrOd
TaJuan Carter

1776 I STREET, NW SUITE 400 WASHINGTON, DC 20006-3708 PHONE 202.739.8088 FAX 202.785.1898

Comments on
NUREG-1738 Technical Study of Spent Fuel Pool Accident Risk at
Decommissioning Nuclear Power Plants

Executive Summary

The Commission issued a Staff Requirements Memorandum dated December 21, 1999, on improving decommissioning regulations for nuclear power plants. The SRM states "The Commission approved the development of a single, integrated, risk informed decommissioning rule for emergency preparedness, insurance, safeguards, operator training and staffing, and backfit." The SRM goes on to direct the staff to ensure all realistic scenarios for offsite consequences are appropriately considered during the rulemaking process.

The approach taken in the staff's technical report for risk informing the decommissioning regulations is not based on realistic scenarios. In fact by compounding overly conservative estimates of seismic risk, pool fragility and the probability and magnitude of the postulated zirconium fire and its consequent releases the report is a worst case estimate. While, the report concludes that the risk is small and that any releases are well below the quantitative health objectives the decisions regarding the continued applicability of emergency preparedness, financial protection and security must be made on the basis of a realistic risk assessment.

Discussion

Overly conservative estimates of seismic risk, pool fragility and the probability and magnitude of the postulated zirconium fire and its consequent releases are compounded to derive what is in essence a worst case estimate. The report also appears to establish a "zero risk" threshold for eliminating requirements for the spent fuel pool. For example, item 3 of the conclusions in the executive summary states "Insurance, security, and emergency planning requirement revisions need to be considered in light of other policy considerations, because a criterion of "sufficient cooling to preclude a fire" cannot be satisfied on a generic basis."

This approach is contrary to the Commission's Safety Goal Policy that states PRA evaluations in support of regulatory decisions should be as realistic as possible. The Safety Goal Policy also states that "PRA and associated analyses (e.g., sensitivity studies, uncertainty analyses, and important measures) should be used in regulatory matters, where practical within the bounds of the state of the art, to reduce unnecessary conservatism associated with current regulatory requirements, regulatory guides, license commitments, and staff practices."

The study provides sensitivity analyses but no effort was made to derive a best estimate of risk. A good understanding of the underlying phenomenology would greatly assist in defining mean estimates and understanding the uncertainty in the estimates. Enclosure 1 provides specific technical recommendations ~~on~~ considerations for deriving a supporting phenomenology. Data is also referenced in the enclosure that demonstrates that the risk of the cask drop damaging the pool sufficiently to cause rapid drain down is likely zero, not one as assumed in the technical report.

Commission actions to establish regulatory requirements ~~based on the staff's~~ technical study may be precedent setting in that the study uses bounding estimates of seismic risk as the basis for assessing the need for continued applicability of emergency preparedness and insurance. Extraordinarily low frequency accidents should not be used as the predominant basis for regulations ~~in an era of risk~~ informed regulations. Most of the seismic risk for draining the pool comes from events with frequencies greater than one in a million years. The risk from these low frequency events should be considered well below that which can be reasonably required for adequate protection of public health and safety.

Enclosure 2 provides a discussion of seismic risk and recommendations on treatment of seismic risk where the risk is the predominant contributor to the overall risk profile. None of the operating plant requirements being considered, i.e., emergency preparedness, financial protection and security, are underpinned with explicit values for acceptable risk. However, if a realistic estimate indicates that the risk of a zirconium fire is negligible then the Commission's decision on whether to mandate these costly ~~requirements is very straightforward.~~

The report's descriptions of ~~events~~ ~~and consequences~~ could be written more clearly ~~For~~ example, the report compares risk from a single event for operating plants (seismic) to a worst case estimate of the total risk from the spent fuel pool. The reader can conclude that pools pose a risk that is comparable to operating plants and therefore should be expected to be subject to operating plant requirements, specifically emergency preparedness, and financial protection.

Industry Recommendations

1. The report should be withdrawn and reissued when the technical basis has been corrected and the report has ~~been~~ subjected to an independent peer review. Although the staff repeatedly emphasizes that the risks are well below the safety goals, this conclusion is insufficient. The informed decisions that must be made regarding the applicability of emergency preparedness, financial protection and security cannot be made without a realistic estimate of risk. Accordingly, industry recommends that the staff develop a phenomenological basis for the events leading to releases from the postulated zirconium fire in

spent fuel pools. These efforts along with efforts to reduce unnecessary conservatism will support development of mean estimates and a characterization of uncertainty that can be used to establish a better estimate of the risk (see enclosure 1 for specific recommendations). Enclosure 2 provides specific recommendations on treatment of seismic risk.

2. A formal peer review should be performed. NRC has stressed to the industry the importance of the peer review process to ensuring quality PRAs. Taking this step for its own study is consistent with R.G. 1.174, which is cited by NRC as the basis for the approach taken in the study.

3. The report should only discuss the risk estimate and the technical basis needed ~~to support the risk~~ estimates. The report should avoid inferring policy decisions that the Commission will make on what constitutes negligible risk for the purpose of evaluating the continued applicability of emergency preparedness, insurance and security.

4. Once the study is revised it is still possible the study may be limited in its usefulness because the generic study may contain many assumptions that don't pertain to specific plant circumstances. The report will only be useful in granting exemptions on a plant specific basis (one of the stated objectives of the study) if the report contains explicit criteria for application of generic risk insights on a plant specific basis. Criteria to be considered, depending on what contributes to the generic risk profile after the study is revised, might include:

   - decay heat
   - the likelihood of draining the spent fuel pool given realistic seismic events,
   - likelihood of cask drops damaging the pool sufficient to drain the pool
   - likely configuration of fuel following an event that could drain the pool
   - likelihood of cladding oxidation propagating beyond assemblies with the highest decay heat
   - time period over which postulated releases could occur, and
   - recovery actions available to eliminate or mitigate potential releases.

5. A clear discussion is needed in the report to characterize the relative risk of spent fuel pools vis a vis operating plants. In addition, the report needs to capture important differences between the conclusions of the generic study and alternate conclusions that may be reached on a plant specific basis when assumptions in the generic study are not applicable at a given plant.

Enclosure 1

Recommended Actions to Complete the Spent Fuel Pool Risk Study and Support Development of a Best Estimate of Risk

The staff's technical study of spent fuel pool accident risk was portrayed as a scoping study or bounding estimate by the staff and the ACRS at a recent Commission briefing (February 20, 2001). However, this important distinction is not featured prominently in the report. The use of bounding estimates does not provide a means to portray risk in a risk-informed framework. As a result, decision makers are unable to use these evaluations to make reasoned judgements. This appears to be contrary to NRC Severe Accident Policy Statement as described in Reg. Guide 1.174:

> "The Safety Goal Policy Statement discusses treatment of uncertainties at some length. It stresses the need to consider potential uncertainties in regulatory decision making. While it adopted mean estimates for implementing the quantitative objectives, it also asserted the need to understand the important uncertainties in risk predictions."

It is recommended that the following actions be taken by the staff to develop realistic estimates of the risk of the releases from spent fuel pools for decommissioning plants.

1. Address the many conservative assumptions in the study that are compounded to arrive at a worst case estimate of risk. Examples include:
   - The "smart" seismic event that drains the pool, but only to the worst case configuration, i.e., within one-foot of the bottom of the pool to block air intakes.
   - The radionuclide release that is used to characterize the consequences is based on a fire engulfing 3.5 cores whereas the report indicates that a maximum of two cores will be involved in the postulated fire at times greater than one-year following discharge of the last core. Even the two-core calculation is strongly dependent on how the fuel is stored, i.e., are the most recently discharged bundles stored adjacent to each other or are they distributed throughout the pool? Overall the combination of worst case assumptions from unique plant configurations of highest fuel burnups permitted by regulation and assuming that those high burnups are reached through one cycle in the reactor is being used to create an "extreme worst case" configuration.
   - No characterization of probability is provided for the assumption of 1% release of fuel fines. While the staff report states the inclusion leads to small increases in offsite consequences, this assumption increases population doses by 50%.

- The 100 cask lifts per year is provided as the basis for a yearly risk of damaging the pool sufficiently to drain the pool. However, based on the staff's estimate of the inventory of fuel in the pool for BWRs and PWRs the entire inventory would be offloaded in from 30-60 casks, resulting in a maximum of 60-120 lifts for the life of the pool. Accordingly this risk should not be treated as a recurring annual risk factor.

2. Cask drop sequence was not adequately analyzed.

Analyses that have a fundamental impact on the probability and consequences of the postulated zirconium fire should be performed. For example, no structural analysis was performed to determine whether a cask drop could actually damage the pool sufficiently to cause a large leak. EPRI sponsored work at Sandia labs (Full-Scale Tornado-Missile Impact Tests, EPRI NP-440, July 1977), NRC sponsored work (Summary and Evaluation of Low-Velocity Impact Tests of Solid Steel Billets onto Concrete Pads, NUREG CR-6608, 1997) and full scale studies sponsored by BNFL provide a significant technical basis showing minimal damage from such drops.

Evaluation of the available data shows that a straightforward criterion can be developed to determine if cask drop could cause a rapid drainage of the spent fuel pool. Application of this criterion to a cask drop through water in an existing fuel pool calculates a damage condition that is an order of magnitude less than that necessary to cause catastrophic failure of the concrete floor or walls. Therefore, the probability of causing a failure that would rapidly drain a spent fuel pool is zero.

3. Mechanistic evaluations are needed to realistically assess consequences.

Mechanistic evaluations of consequences of the postulated zirconium fire should be performed in a manner consistent with the available experimental database. For example, experiments have shown that the degree to which the fuel oxidizes determines the amount and rate of cesium and ruthenium releases. Sensitivity studies show that for fuel that has been out of the reactor for one to three years, assuming a small and large release of ruthenium, effects the consequences by two orders of magnitude. Currently, the report merely provides the results of this sensitivity analysis, i.e., shows consequences of negligible and one hundred percent ruthenium release.

Data exists to permit a best estimate to be formulated. A best estimate should be developed and reported in addition to the results of the sensitivity analyses. The CODEX and TMI-2 data and MELCOR code provide parts of the technical basis that can be used to estimate the extent of oxidation that can occur before the fuel and cladding melt, liquefy, and then slump. Once material relocation occurs the amount of cladding and fuel exposed to further oxidizing by air or steam is significantly reduced. Fission product release tests performed at ORNL (Test VI-7) and Chalk River (Test H02) with irradiated fuel heated in air indicate that all cladding and fuel must be oxidized before any significant ruthenium releases are observed.

The TMI-2 experience indicates that a small fraction of fuel could be left as small declad (without cladding) pieces/pellets on top of the rubble bed. These would have an opportunity to be further oxidized. Because the top of the bed would be subject to radioactive cooling any oxidation occurring would take place at lower temperatures and consequently would occur over a very long period of time, several days to months.

4. Analyses are needed to establish a time frame for potential recovery actions.

   Evaluations are needed to assess the leakage rates from the pool following a cask drop or seismic event. Furthermore all mechanisms for cooling, including the results of vaporization of water in the lower regions of the pool and estimates of natural circulation through the bundles at various levels of pool drain down should be assessed to better represent the rate of fuel heat up for the postulated events.

   Preliminary industry evaluations indicate that the postulated event might evolve over very long periods of time, e.g., days to months. Potential recovery actions should be evaluated commensurate with the best estimates of time available.

Enclosure 2

Treatment of Seismic Risk

Introduction

The report's treatment of seismic risk should be re-evaluated. The report characterizes risk of a zirconium fire in the spent fuel pool based on bounding estimates of seismic risk. Further, because of the inherent robustness of spent fuel pools; most of the seismic risk comes from very low frequency initiators. Very low frequency initiators should not be used as the predominant basis for regulations in an era of risk informed regulations. At some point the frequency of seismic events become so low that their consideration is below that which is necessary for adequate protection of public health and safety. Accordingly, the prioritization of NRC and industry resources to address these worst case accident sequences regardless of probability may be an imprudent use of resources.

Regulatory Guide 1.174 states deterministic and probabilistic approaches should be used in an integrated fashion. Although deterministic approaches for evaluating the seismic hazard were fully developed and included in appendices to the report, the report does not make good use of the findings in characterizing the seismic risk for the report's readers. Further, the report implies that industry would incur large costs from application of a seismic checklist to confirm that the pools have a high confidence of low probability of failing at seismic events 2-3 times the safe shutdown earthquake. These costs do not appear to confer commensurate benefit in terms of reduction of costly emergency preparedness and financial protection requirements that were in place when the plant was operating. By contrast, the staff appears to be using a zero risk standard for evaluating the applicability of these requirements.

Commission safety goals are based on quantitative numbers that are a ratio of nuclear to non-nuclear risks (e.g., the probability of an early fatality should not exceed 1/1000 of the "background" accidental death rate). The staff provided estimates of the amount of collateral non-nuclear damage resulting from severe earthquakes that could damage the pool in an appendix to the report, but the concept was not included in the main body of the report where risk is discussed. When criteria are developed for what constitutes negligible risk for purposes of evaluating the need for protective requirements, these criteria should consider the collateral non-nuclear damage that will occur when very large, very low probability seismic events are the predominant contributor to the overall risk.

Discussion

I. Estimates of seismic risk are bounding

The report states in several places that the EPRI and LLNL seismic hazard curves are equally valid. However, the report also states that sites on the east coast that don't meet the staff's pool performance risk guidelines under the LLNL hazard estimate would be required to perform additional analyses if those sites request exemptions from emergency planning or financial protection. The staff's deferral to the more conservative LLNL curves when the EPRI curves are stated to be equally valid does not reflect the tenets of a risk informed approach as directed by agency policy and guidance. The EPRI curves most likely represent a very conservative estimate of seismic risk due to the conservatism in the estimate of a generic pool fragility value and the large amount of uncertainty inherent in predicting very low frequency events. These low frequency events contribute 95% of the seismic risk.

The staff extended LLNL seismic hazard curves beyond the return periods typically used for evaluating seismic risk at operating plants and requested that industry provide similar extensions for EPRI seismic hazard curves for the purpose of the spent fuel study. Figures 1-3 show the distribution of seismic risk across peak ground accelerations for spent fuel pools at three sites on the east coast. Note that for the Surry pool the 50th percentile of the annual probability of exceedance is 1 in a million years between peak ground accelerations of .5 and .6 g. In fact, the preponderance of the seismic risk is attributable to very low probability very large seismic events. For Surry an examination of Figure 3 reveals that 95% of the risk occurs at levels in excess of 0.5 g, 3 times the safe shutdown earthquake (SSE) for this plant; 60-plus% of the risk comes from seismic events exceeding 1.0g, 4-5 times the SSE for this plant.

The ability to address seismic events that are not expected to occur is exacerbated by the fact that the tails of the curves are driven by uncertainty. For example, an examination of Figure 4 reveals that uncertainty increases from a factor of 10 in the realm of plausible earthquakes to a factor of 1600 at earthquakes of 1.0g. The diverging nature of the uncertainty curves means that real improvements in seismic capacity will be masked by uncertainty, as seismic events become larger, and more implausible. In addition, risk estimates are likely to be highly overly conservative at the high ground motion levels predicted for seismic events of this size.

Probabilistic analyses should be performed because these analyses define the upper boundaries.[1] However, a lower limit based on curves that are truncated at certain very low return frequencies, should be employed for regulatory decision making regarding the need for protection requirements. For example, risk estimates for regulatory purposes based on return frequencies not exceeding E4 –E5 at the 50th percentile makes it clear to stakeholders that very low frequency events are outside the boundaries for practical decision making.

II. Deterministic and probabilistic approaches should be used in evaluating the acceptability of seismic risk.

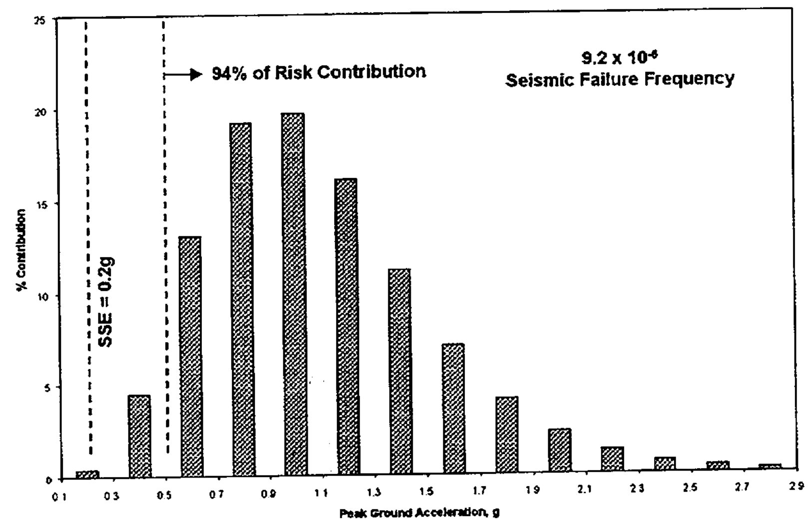
The staff concludes that pools are inherently rugged and likely to have seismic capacities beyond the 0.5g value used in the seismic checklist developed to confirm robustness of pool designs. The report concludes that the seismic risk upon successful implementation of the checklist is acceptable: estimates of the mean risk for pools on the east coast are 2 E-7 using EPRI curves and 2 E-6 using LLNL curves. However, the finding that the risk is acceptable was never reconciled with subsequent treatment of the risk. As noted above, in some places the report appears to be applying a zero risk standard. In other places the report states that plants not meeting the pool performance guideline using the LLNL risk curves must perform additional analyses as a basis for requesting exemptions to emergency preparedness and financial protection requirements. The latter discussion implies that the staff has established but not explicitly stated a non-zero risk value that can be used to evaluate the necessity of emergency preparedness and financial protection requirements. Clearly defined criteria should be established by integrating the probabilistic and deterministic insights.

Any use of the seismic checklist developed by NRC needs to be carefully evaluated. Application of the checklist as currently drafted equates to requiring licensees to perform a slightly simplified fragility analysis of their pools. Industry estimates the cost of this simplified fragility analysis to be on the order of $50,000.00 per pool evaluated. These costs do not include internal plant resources that would be needed to support the consultant's efforts. To retain these costly requirements and require a seismic evaluation when the plant shuts down would be nonsensical and unsupportable. These requirements (EP, insurance and security) were considered adequate to address a range of accident events and sequences when the plant was operating. In addition, the seismic capacity of the plant and pool were also considered to be acceptable during plant operations. To retain these requirements and require further seismic analysis for a single accident sequence based on seismic risk that is several times higher than the design basis of the plant is unsupportable.

[1] We believe fewer insights are forthcoming from analyses using expanded seismic hazard curves for spent fuel pools than might be forthcoming for operating plants, i.e., the simple massive design of the pool will fail beyond some level. Nonetheless, the analysis should be performed.

Acceleration Range Contribution to Spent Fuel Pool Structural Failure Probability - Robinson

Figure 1

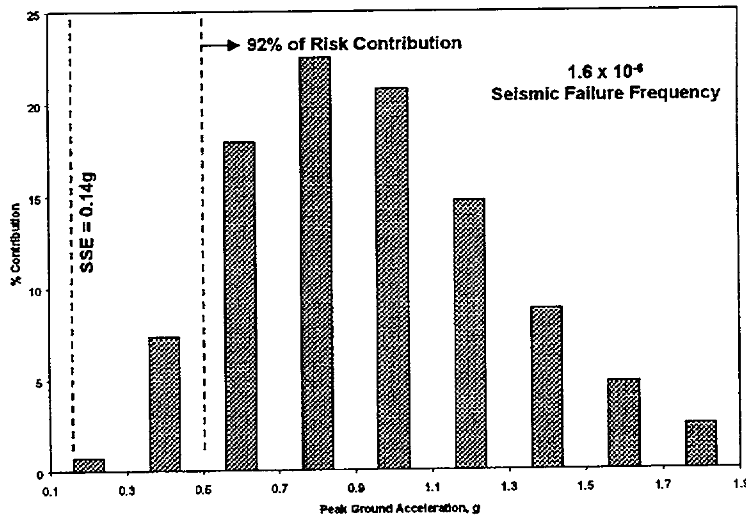


M:\dew\epri\risk informed project\task 11\all seismic spent fuel.ppt

Seismic failure frequency is calculated by integrating the product of the conditional probability of failure (called seismic fragility) and the frequency of occurrence of earthquakes over all values of peak ground acceleration. This procedure is called "convolution". For example, the mean seismic failure frequency of spent fuel pool structure at Robinson is calculated as 9.2×10^{-6} per year. This value includes contribution from different levels of ground acceleration. The above plot shows this contribution. For example, about 4 percent of the failure frequency is contributed by earthquakes in the range of 0.3g to 0.5g peak ground acceleration. It can be seen that 94 percent of the failure frequency comes from earthquakes with peak ground acceleration in excess of 0.5g. This situation arises from extrapolation of the hazard curves beyond the range of empirical evidence and the large uncertainty that the experts associate with the hazard at higher ground motion levels. It is comforting to observe that the spent fuel pool structure does not have seismic vulnerability at earthquakes less than 0.5 g peak ground acceleration and any upgrading of the structure beyond 0.5 g will not materially reduce the risk at higher levels. Further, the risk from higher levels comes mainly from extrapolations that are highly controversial.

Acceleration Range Contribution to Spent Fuel Pool Structural Failure Probability – Vermont Yankee

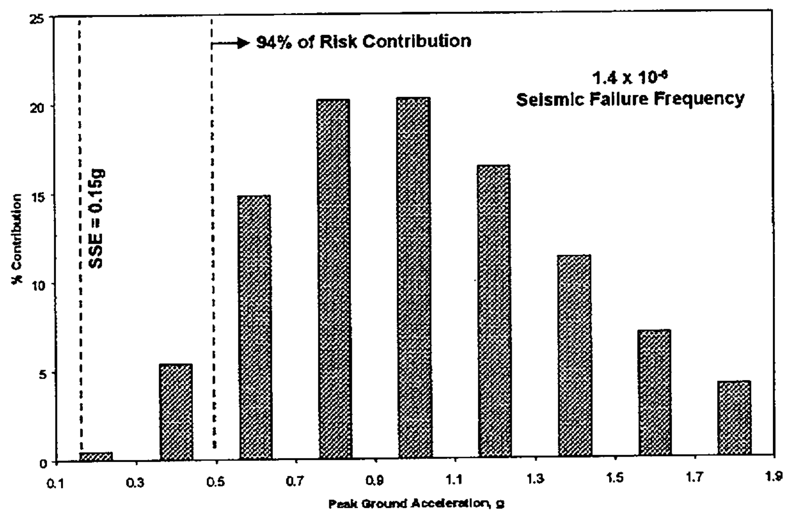
Figure 2



M:\dew\epri\risk informed project\task 11\all seismic spent fuel ppt

Acceleration Range Contribution to Spent Fuel Pool Structural Failure Probability – Surry

Figure 3

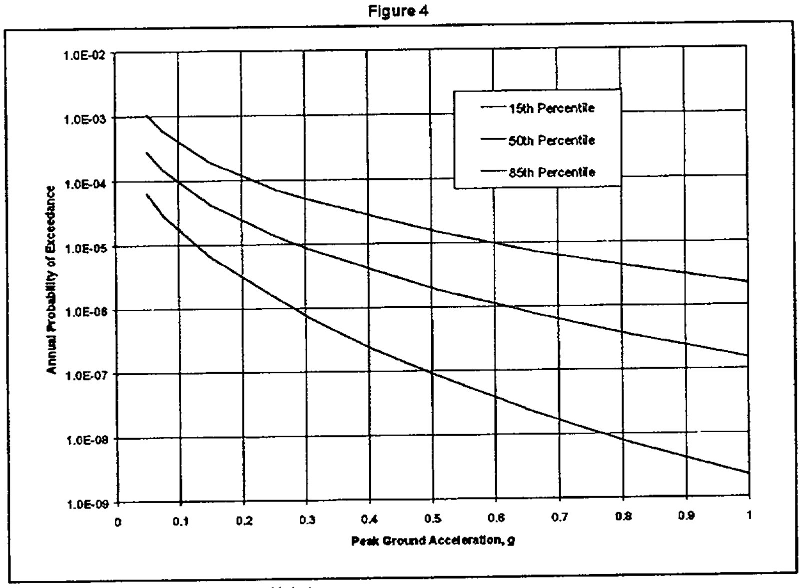


M:\daw\epri\risk informed project\task 11\all seismic spent fuel ppt

7

Surry Hazard Curves

Figure 4



M:\daw\apn\risk informed project\task 11\a1 seismic spent fuel.ppt

This figure shows the seismic hazard curves for Surry. It is a plot of the annual probability of exceedance (called seismic hazard) of different levels of ground motion expressed in terms of peak ground acceleration. Different curves depict the uncertainty in the seismic hazard assessment obtained through a detailed expert elicitation process. The middle curve - median hazard curve - indicates that half of the experts judge the hazard to be below this level. The top curve - 85 percentile curve- shows that 85 percent of the experts judge the hazard at the site to be less than given by this curve. The bottom curve -15 percentile curve - indicates that only 15 percent of the experts judge the hazard to be lower than given by this curve. At low peak ground acceleration values, the spread between the top and bottom curves is small since there is empirical data available for validation. At higher peak ground acceleration values, the spread is much wider reflecting the paucity of data and much reliance on expert opinion.