Appendix 4C Pool Performance Guideline

Introduction

The Pool Performance Guideline (PPG) provides a threshold for controlling the risk from a decommissioning plant spent fuel pool (SFP). By maintaining the frequency of events leading to uncovery of the spent fuel at a value less than the recommended PPG value of 1E-5 per year, zirconium fires will remain highly unlikely, the risk will continue to meet the Commission's Quantitative Health Objectives [1], and changes to the plant licensing basis that result in very small increases in LERF may be permitted consistent with the logic in Regulatory Guide 1.174 [2]. The purpose of this appendix is to present the rationale for the PPG, and to illustrate how conformance with the recommended PPG will assure that spent fuel pool risk in decommissioning plants will continue to meet the Commission's quantitative health objectives (QHOs).

Regulatory Guide (RG) 1.174, "An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis," contains general guidance for application of PRA insights to the regulation of nuclear reactors. The same concepts can also be applied in the regulation of spent fuel pools. The guidelines in RG 1.174 pertain to the frequency of core damage accidents (CDF) and large early releases (LERF). For both CDF and LERF, RG 1.174 contains guidance on acceptable values for the changes that can be allowed as a function of the baseline frequencies. For example, if the baseline CDF for a plant is below 1E-4 per year, plant changes can be approved that increase CDF by up to 1E-5 per year. If the baseline LERF is less than 1E-5 per year, plant changes can be approved that increase LERF by up to 1E-6 per year.

For decommissioning plants, the risk is primarily due to the possibility of a zirconium fire associated with the spent fuel cladding. The consequences of such an event do not equate directly to either a core damage accident or a large early release as modeled for an operating reactor. Zirconium fires in spent fuel pools potentially have more long term consequences than an operating reactor core damage accident because: there may be multiple cores involved; the relevant clad/fuel degradation mechanisms could lead to increased releases of certain isotopes (e.g., short-lived isotopes such as iodine will have decayed, but the release of longer-lived isotopes such as ruthenium could be increased due to air-fuel reactions); and there is no containment surrounding the SFP to mitigate the consequences. On the other hand, they are different from a large early release because the postulated accidents progress more slowly, allowing time for protective actions to be taken to significantly reduce early fatalities (and to a lesser extent latent fatalities). In effect, a spent fuel pool fire would result in a "large" release, but this release would not generally be considered "early" due to the significant time delay before fission products are released.

Even though the event progresses more slowly than an operating reactor large early release event and the isotopic make-up is somewhat different, the consequence calculations performed by the staff (reported in Appendix 4 and 4A) show that spent fuel pool fires could have significant health effects on par with those for a severe reactor accident. These calculations considered the effects of different source terms, evacuation assumptions, and plume-related parameters on offsite consequences. Since an SFP fire scenario would involve a direct release

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to the environment with significant consequences, the staff has decided that the RG 1.174 LERF baseline guideline of 1E-5 per year (the value of baseline risk above which the staff will only consider very small increases in risk) provides an appropriate threshold for controlling the risk from a decommissioning plant SFP, and has established 1E-5 per year as the recommended PPG for this purpose. Maintaining the frequency of events leading to uncovery of the spent fuel at a value less than the PPG, will assure that zirconium fires remain highly unlikely and that the risk in a decommissioning plant will continue to meet the Commission's QHOs, as discussed below. Conformance with the PPG is also essential if the staff is to permit changes to the licensing basis that result in small increases in risk, such as relaxations in Emergency Preparedness requirements.

Our conclusion in the draft final report was that, even though there are some differences in source term and timing, scenarios involving a spent fuel pool zirconium fire would result in population doses that are generally comparable to those expected from accident scenarios involving a large early release at operating reactors, and therefore a PPG of 1E-5 per year was appropriate. The staff has reassessed these conclusions following the performance of additional consequence calculations in Appendix 4A and 4B that took into account the possibility of significant ruthenium release fractions. This assessment was undertaken to address concerns raised during review of the draft final report that large ruthenium releases from a spent fuel fire could substantially increase both early and latent health effects, as well as shift the controlling decision criteria from early fatalities to latent health effects due to the combined effect of longer times for evacuation and longer ruthenium half life.

In reassessing the appropriateness of the 1E-5 per year PPG as discussed below, the staff contrasted the SFP risk for a licensee maintaining its facility at the PPG with the Commission's Safety Goal Policy Statement. The Policy Statement expressed the Commission's policy regarding the acceptable level of radiological risk from nuclear power plant operation as follows:

- Individual members of the public should be provided a level of protection from the consequences of nuclear power plant operation such that individuals bear no significant additional risk to life and health

- Societal risks to life and health from nuclear power plant operation should be comparable to or less than the risks of generating electricity by viable competing technologies and should not be a significant addition to other societal risks.

The following quantitative health objectives (QHOs) are used in determining achievement of the safety goals:

- The risk to an average individual in the vicinity of a nuclear power plant of prompt fatalities that might result from reactor accidents should not exceed one-tenth of one percent (0.1 percent) of the sum of prompt fatality risks resulting from other accidents to which members of the U.S. population are generally exposed.

- The risk to the population in the area near a nuclear power plant of cancer fatalities that might result from nuclear power plant operation should not exceed one-tenth of one percent (0.1 percent) of the sum of cancer fatality risks resulting from all other causes.

These QHOs have been translated into two numerical objectives as follows:

- The individual risk of a prompt fatality from all "other accidents to which members of the U.S. population are generally exposed," such as fatal automobile accidents, is about 5E-4 per year. One-tenth of one percent of this figure implies that the individual risk of prompt fatality from a reactor accident should be less than 5E-7 per reactor year.

- "The sum of cancer fatality risks resulting from all other causes" for an individual is taken to be the cancer fatality rate in the U.S. which is about 1 in 500 or 2E-3 per year. One-tenth of one percent of this implies that the risk of cancer to the population in the area near a nuclear power plant due to its operation should be limited to 2E-6 per reactor year.

Although the Policy Statement and related numerical objectives were developed to address the risk associated with power operation, is it reasonable to require that these objectives continue to be met for as long as nuclear materials remain on the plant site. Accordingly, the staff has compared the risks to an individual with the QHOs, assuming the licensee maintains the facility at the recommended PPG of 1E-5 per year. The relevant risk measures are the early fatality risk to an average individual within 1 mile of the plant, and the latent cancer fatality risk to an average individual within 10 miles of the plant. These measures would not be significantly impacted by population density since they are determined on the basis of the risk to the average individual.

Appendix 4B of this report provides the results of offsite consequence calculations for a SFP fire occurring at various times following final shutdown at a hypothetical 3441 MWth BWR spent fuel pool located at the Surry site. Additional calculations provided in Appendix 4A address the sensitivity of early and latent health effects to source terms, time of evacuation, percent of population participating in the evacuation, population distribution, number of cores participating in the SFP fire, and plume-related parameters. The risk measures corresponding to the above numerical objectives were calculated using the MACCS2 computer code for each of the cases reported in Appendix 4B (i.e., low and high ruthenium source term with both early and late evacuation), and for the worst case SFP accident source term reported in Appendix 4A. The latter case, identified as Case 45a, corresponds to a complete release of the volatiles (cesium and iodine) and ruthenium, a 0.01 release of fuel fines, and late evacuation of 95% of the population. The results are reported in Table 1. For comparison with the numerical objectives, the staff assumed that the licensee maintains the facility at the recommended PPG of 1E-5 per year.

The risk results indicate that at a PPG of 1E-5 per year, the QHOs would continue to be met for even the most severe cases considered in Appendix 4A and 4B. The margins to both QHOs are substantial (about two orders of magnitude) for the case with early evacuation even with the large ruthenium release. The margins are considerably reduced in the late evacuation cases, but sufficient to conclude that the QHOs would be met given the bounding nature of the source terms and fission product inventories used in these calculations.

The margin to the QHO is smallest (i.e., the percent of QHO is the largest) for early fatality risk. Thus, similar to severe accidents in operating reactors, acceptable levels of risk for a SFP

accident would be controlled by the early fatality risk measure. The margins to the QHO observed in these calculations suggest that the recommended PPG of 1E-5 per year provides an appropriate level of safety.
The role of the PPG in plant-specific implementation of regulatory changes for decommissioning plants will be established as part of the integrated rulemaking. In one possible approach shown in Figure 1, a licensee that fully complies with all IDCs and SDAs (including the seismic checklist) might be permitted to implement changes under the revised rule without a plant-specific analysis and detailed staff review. However, if the licensee/site does not comply with all of the IDCs and SDAs, a plant-specific analysis of SFP risks would be required in order to support relaxations to existing regulations. The PPG could be used to establish an acceptable level of risk in the review of such submittals.

Conclusions

The frequency of events leading to uncovery of the spent fuel must be less than 1E-5 per year in order to consider risk-informed changes that could result in the equivalent of a 1E-6 per year increase in LERF. Based upon the above comparisons, the staff believes that the LERF-based pool performance criteria of 1E-5 per year is reasonable and appropriate. This is supported by the comparisons that show that the conditional health effects for SFP fires are generally in the range of health effects considered for severe accidents in operating reactors, and that the Commission's QHOs continue to be met for SFP fires even if the ruthenium release fraction is substantially increased. Given these observations, there does not appear to be sufficient justification to revise the proposed pool performance guideline of 1E-5 per year which was developed from the RG 1.174 LERF considerations.

In the above comparisons, the SFP accident is assumed to occur one year following shutdown. The consequences of the accident would be markedly lower if it were to occur at a later time due to fission product decay. Specifically, after about 5 years the contribution from ruthenium would be virtually eliminated, and consequences would be dominated by cesium. Accordingly, the results reported for the low ruthenium source term would be most representative for events occurring 5 years or beyond.

Although the above comparisons focus on the Surry site, the results are expected to be generally applicable to other sites as well. At higher population sites the SFP accident consequences would be higher, but the risk associated with reactor accidents would be proportionally higher as well. Thus, the results of the relative comparisons should remain valid. Similarly, the QHOs represent risk to the average individual within 1 mile and 10 miles of the plant, and should be relatively insensitive to the site-specific population.

It should also be acknowledged that long term health impacts are sensitive to public policy decisions such as land interdiction criteria for returning populations. The long term protective assumption used in both the NUREG-1150 and SFP studies was to interdict land which could give a projected dose to an individual via the groundshine and resuspension inhalation pathways of more than 4 rem in 5 years (2 rem in the first year and 0.5 rem per year for the next 4 years, for an average of 800 mrem per year). Comparisons of consequence results at various distances for each of the NUREG-1150 reference plants are provided in NUREG/CR-6349, and clearly show that the increase in population dose with distance is due to a large number of

people receiving very small doses, below the assumed long-term interdiction limit of 4 rem in 5 years, since the offsite consequences due to land condemnation, etc., remain essentially the same over the range of distances. The effect of varying long-term interdiction dose limits on population doses, latent fatalities, and offsite costs was estimated in NUREG/CR-6349 by recalculating the consequences for each of the NUREG-1150 plants for various lower limits. The results show that as the interdiction limit is reduced, the population dose and latent cancers decrease and the offsite costs progressively increase. For a reduction in the interdiction limit from 800 mrem per year to 300 mrem per year the risk measures decreased by typically 20 to 30 percent, and offsite costs increased by about a factor of two. Thus, changes in risk results on this order can be expected as a result of public policy decisions.

Finally, in comparing the SFP consequences with those for a reactor accident at Surry it should be kept in mind that the NUREG-1150 results for Surry are for a power level of 2441 MWth, and that the SFP consequences will be overstated slightly due to the different power levels.

References

1. Safety Goals for the Operations of Nuclear Power; Policy Statement, 51 Federal Register 28044, August 4, 1986.

2. Regulatory Guide 1.174, "An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis," July 1998.

3. U.S. Nuclear Regulatory Commission, *Evaluation of Severe Accident Risks: Surry Unit 1*, NUREG/CR-4551, Vol. 3, Rev. 1, Part 1, Sandia National Laboratory, October 1990.

4. U.S. Nuclear Regulatory Commission, *MACCS Version 1.5.11.1: A Maintenance Release of the Code*, NUREG/CR-6059, Sandia National Laboratory, October 1993.

Table 1 - Comparison of Spent Fuel Pool Accident Risk One Year After Shutdown with Quantitative Health Objectives (QHOs)

Case	QHO for Individual Risk of Prompt Fatalities					QHO for Societal Risk of Latent Cancer Fatalities				
	Ind. Early Fatality Risk (per event)	PPG (events per year)	Prob of Early Fatality (per year)	QHO (per year)	% of QHO	Ind. Latent C. Fatality Risk (per event)	PPG (events per year)	Prob of Latent C. Fatality (per year)	QHO (per year)	% of QHO
Low Ruthenium Source Term, Early Evacuation	5.44E-4	1E-5	5.44E-9	5E-7	1	9.09E-4	1E-5	9.09E-9	2E-6	<1
Low Ruthenium Source Term, Late Evacuation	7.13E-3	1E-5	7.13E-8	5E-7	14	1.68E-2	1E-5	1.68E-7	2E-6	8
High Ruthenium Source Term, Early Evacuation	1.50E-3	1E-5	1.50E-8	5E-7	3	4.33E-3	1E-5	4.33E-8	2E-6	2
High Ruthenium Source Term, Late Evacuation	3.46E-2	1E-5	3.46E-7	5E-7	69	8.49E-2	1E-5	8.49E-7	2E-6	42
Worst Source Term in App. 4A, Late Evacuation	3.66E-2	1E-5	3.66E-7	5E-7	73	5.16E-2	1E-5	5.16E-7	2E-6	26

Figure 1 - Use of the PPG in Review of SFP Risk Submittals