May 3, 2001

Richard Olsson
Swedish Nuclear Power Inspectorate
S-106 58 Stockholm, Sweden

SUBJECT: RESPONSES TO COMMENTS ON THE *TECHNICAL STUDY OF SPENT FUEL POOL ACCIDENT RISK AT DECOMMISSIONING NUCLEAR POWER PLANTS (NUREG-1738)*

Dear Mr. Olsson:

Thank you for your comments provided on April 4 and April 25, 2000, on the final draft of the above report. We appreciate your review of and interest in our ongoing work. We have addressed your comments Enclosure 1. We are also providing you with copies of the published version of NUREG-1738 and copies of two other NRC reports that you requested.

Sincerely,

/RA/signed by T. Collins

Timothy E. Collins, Deputy Director
Division of Systems Safety and Analysis
Office of Nuclear Reactor Regulation

Enclosures: As stated

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Responses to Comments from the Swedish Nuclear Power Inspectorate (SKI)

The NRC staff did not respond to all of the SKI comments in the Decommissioning Spent Fuel Pool Risk Study (NUREG-1738). For comments that were addressed in the report, the comment number is provided. If the wording of the comment differed from the original wording by SKI, both comments were provided.

Comments from Mats Sjöberg/Ferenc Müller on April 5, 2000:

1. Does IDC #3, also include means of communication?

Response: Yes, it is expected that with this commitment that a means of communication is ensured.

2. IDC #4, is there a new Tech. Spec (for shut down plants) in place. In that case, are the emergency diesels at the plant still operable? Or is this a higher expectation (than during operation of the plant) to provide electricity and water supply?

Response: There is not a standard technical specification for emergency power to supplement onsite power. To date, U. S. decommissioning plants have custom technical specifications. For example, one plant has a requirement to have a backup power source or a non-electric water source within 24 hours of losing makeup capability. However, most plants do not have this type of technical specification. The emergency diesel generators that are used for emergency on-site power during operation are removed during decommissioning. We found that decommissioning plants typically have a diesel-powered pump that is capable of pumping water into the spent fuel pool, if needed.

3. Licensing limits of Zr-fire. It is very conservative to use 570^{o}C as a licensing limit (gap-release temperature).

   Comment #67: The gap release temperature is too conservative for a success criterion.

Response: The gap release temperature is the temperature at which the cladding can blister and allow gases trapped between the fuel pellets and the cladding to escape. The temperature criterion for gap release may also be the threshold for releasing fuel fines and ruthenium. In the study, we evaluated other less conservatives temperatures for a success criterion, and defined four scearios that could use a less conservative criterion. This is discussed in Appendix 1b.

4. Fire propagation/radioactivity releases. We think it is probable that the Zr-fire, which starts in a fuel element with the highest burnup rate stays within that fuel element. It is very hard to conceive that this fire can propagate to the whole SFP, which also includes fuel from several years old fuel cycles. Limits on fire propagation will directly limit the possible radioactivity releases.

   Comment #68: Fire propagation to low powered fuel is unlikely.

Response: As the fuel decays, the involvement in a fire becomes less likely. However, sufficient research has not been performed to define clear limits of propagation. We, therefore, assumed the involvement of 3.5 cores in our analysis based upon previous analyses (NUREG/CR-0649, “Spent Fuel Heatup Following Loss of Water During Storage, March 1979" and

NUREG/CR-4982, “Severe Accidents in Spent Final Pool in Support of Generic Safety Issue 82, July 1987”). This assumption is discussed in Section 3 and Appendix 4 of the report.

Additional response note: In the early 1980's, Sandia National Laboratory performed some experiments and found that propagation could occur if the adjacent bundle could heat up by decay heat to within 100°C of the oxidation temperature. Unfortunately, this project was not completed.

5. An U.S. earthquake response spectra 10^{-5} (0.5g) is considered as an 10^{-7} in Sweden. Does this justify exemption from further consideration, due to low yearly frequency for Zr-fire? The SFP at the Swedish plant is calculated with an earthquake of 0.1g, see response spectra Figure 1, and found to comply with the Swedish standard design standard.

Response: The threshold for an event that leads to a zirconium fire no longer being considered a concern is a policy decision of which the NRC is currently considering. In part, it is dependent on the type of specific regulation in question. The NRC has regulations that consider beyond design-basis accidents that produce conditions beyond the design standard. In this study, we considered some of these regulations, such as emergency preparedness and insurance. The importance of complying with the Swedish design standard would be dependent on the type of accidents the plant is protecting against.

6. Comment #45: Has the NRC considered the events with the “second” worst off-site consequences at decommissioning plants? For example, in another country which has nuclear power plants, a fire in the bitumen storage (waste handling area) was found to have the second worst, although limited, off-site consequences.

Response: This study evaluated a spectrum of potentially severe spent fuel pool accidents. However, before off-site EP at a decommissioning plant could be eliminated, a licensee would need to perform reviews of their facilities to ensure that there are no other possible accidents that could result in off-site consequences exceeding the U. S. Environmental Protection Agency (EPA) protective action guidelines per existing requirements under 10 CFR 30.32(i) and 10 CFR 30.72.

7. Comment #8: Is a gap release considered to give moderate off-site consequences at the time when a zirconium fire is no longer a threat?

Response: As time elapses (increases) after a plant has permanently shutdown, the fission product inventory available for release gets smaller and the decay heat power decreases. As a result, there may not be sufficient energy to carry released-fission products out of the spent fuel pool and to off-site. NUREG/CR-4982, *“Severe Accidents in Spent Fuel Pools in Support of Generic Safety Issue 82*, July 1987,” provides societal doses for SFP accidents involving a fuel melt release and a gap release at 1 year after final shutdown. These societal doses are $3x10^6$ person-rem and 4 person-rem for a fuel melt release and a gap release, respectively (assumed constant population density of 100 persons per square mile within a 50 mile radius). At one year, a gap release is expected to give a negligible off-site radiological consequences. This study did not calculate the consequences of a gap release.

8. Comment #91: What does “reducing unnecessary regulatory burden” mean in practice, when it comes to emergency planning? What kind of reductions are foreseen for the following: manpower on-site/off-site, emergency equipment, communication means, alarm means, notification of personnel/public, EP, plans, KI [potassium iodide], EPZ [emergency planning zone] radius?

Response: The specific reductions in the areas mentioned are beyond the intent of this study and will be determined during the NRC rulemaking process. Generally speaking, it is anticipated that on-site manpower could be reduced early in the decommissioning process, provided that adequate personnel are available for emergency response duties. Off-site manpower needs, equipment, communication, alarms, notifications, plans, and planning areas would be relaxed consistent with the relaxation of requirements for off-site emergency planning. The consideration of the use of KI would not be necessary when iodine releases are no longer a concern.

9. Requested electronic copies of NUREG/CR-4982 and NUREG/CR-6451

Response: Electronic copies are not available. Instead of electronic copies, the NRC has enclosed paper copies of the requested reports.

Response note: Regarding NUREG/CR-6451, the NRC staff would like to note that it has found deficiencies in the SHARP code and thus has discontinued its use for regulatory decisions.

Comments from Mats Sjöberg/Ferenc Müller on April 25, 2000:

1. Page A1-7 in the report says: “When zirconium reaches temperatures where air oxidation is significant, the heat source is dominated by oxidation. The energy of the reaction is 262 kcal per mole of zirconium. In air, the oxidation rate and the energy of the reaction is higher than zirconium-steam oxidation.”

   We can transfer 262 kcal to other units:

   262 kcal per mol Zr = 1.1 MJ per mol Zr (1 mol Zr = 91.2 kg Zr) = 1.1E+06/91.2 = 1.2E+04 J/kg Zr. We can conclude that the air oxidation energy according to the report is = 1.2E+04 J per kg Zr

   The corresponding values for Zr-steam reaction in the Melcor manual = 6.43E+06 J/kg Zr (Ref. Bottom Head Package, Reference Manual, Table 3.6. Heats of reaction at 1,700 K). The Maap code uses 6.18E+08 J per mol Zr = 6.78E+06 J/kg Zr, for Zr-steam reaction, i.e. near the same as Melcor.

   There is a factor 500 difference in the oxidation energy and to the wrong direction.

   Comment #70: The energy of reaction for air oxidation in the draft report is incorrect.

Response: The staff confirmed that the draft report is correct. Although we were unable to find the specific value referenced to the MAAP code (6.18E+08 J per mol Zr), it appears to be based upon assuming 92 kg of Zr per mole (i.e., a kg-mole). In this case it would be clearer if the oxidation energy were written as 6.18E+08 J per **kg-mol** Zr. The staff’s value of 262 kcal per mole is based upon the gram-mole convention (i.e., one mole=92 grams of Zr). When the values are compared on a consistent mole basis, the oxidation energies are likewise consistent.

2. Release Fractions, Page A4-5, Table A4-3. 100% release is assumed for noble gases, iodine and cesium. We feel that this is too conservative. The latest estimates by the Swedish Radiation Protection Institute for the Tjernobyl case says that 100% of the noble gases, 50-60% of the iodine and 20-40% of the cesium were released at the accident.

Response: In the study, the staff performed several sensitivity studies that varied the release fractions to 75 percent for iodine and cesium. A discussion of the use of the radioactive inventories and sensitivity studies is provided in Appendices 4 and 4A of NUREG-1738. The final release fractions of radionuclides assumed in the off-site consequence analyses for the generic spent fuel pool study are largely based on the release fractions determined appropriate for severe reactor accidents as documented in NUREG-1465, "Accident Source Terms for Light Water Nuclear Power Plants." This is particularly true for the release fractions of the volatile fission product species. Once the spent fuel heatup reaches the point of rapid and escalating zirconium oxidation, the degradation of the affected spent fuel proceeds similar to severe reactor accidents. Thus it was judged that for the affected fuel, the release fractions would be comparable. The release fractions in NUREG-1465 were drawn from a consideration of risk significant accidents identified in past probabilistic evaluations of reactor plants. While the estimated Chernobyl releases may differ from the assumed release fractions for the volatile form of cesium in our study (iodine and noble gases were irrelevant to our study because of decay), this may be attributed to the differences between the Chernobyl accident and a spent fuel pool accident involving massive heatup of the spent fuel pool. Differences may also arise when comparing release fractions from the fuel (as used in our study) and values estimated from offsite sampling at Chernobyl. Treatment of the offsite release in our study assumed all of the inventory released from the fuel was available in the plume to be transported offsite, whereas in some accidents deposition may occur onsite depending on the degree of confinement or containment. The NRC evaluation did not attempt to resolve that level of uncertainty.