MEETING THE NRC GUIDANCE ON BURNUP CREDIT

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ABSTRACT

The NRC has approved submittal of burnup credit applications for transport casks by issuing "Spent Fuel Project Office Interim Staff Guidance-8." Unfortunately, due to its brevity, a number of details are left to the cask vendors. The NRC has been clear that it does not wish to restrict cask vendors since there may be cask specific information important to burnup credit. Based on various meetings with the NRC a more detailed interpretation of what would comprise a reasonable burnup credit license submittal is presented.

1. INTRODUCTION

Spent fuel storage and transportation casks being designed now for PWR fuel will use burnup credit. Four different cask vendors have already announced burnup credit designs.[1,2,3,4] Burnup credit allow for higher capacity casks which reduces the total number of handling operations and shipments. This in turn provides increase safety to public. Although cask vendors are designing burnup credit casks, no burnup credit license applications (since the NRC has allowed their submittal) have been submitted to the NRC. DOE spent over ten years resolving issues on burnup credit with the NRC. This effort culminated with the submittal of a topical report on burnup credit for PWRs.[5] After revision 2, DOE backed off to allow the private industry to take over. In order to aid in that, on May 17, 1999, the NRC issued its "Interim Staff Guidance - 8, Revision 0 (ISG-8R0)."[6] In revision 0 the NRC's guidance was to use 50% of what was applied for in DOE's Topical Report. The NRC stated that it would work to increase the allowable burnup credit and less than three months later the NRC issued their first revision (ISG-8R1).[7]

In revision 1 of their interim staff guidance, the NRC was brief, sticking to the large issues. This allows for generous interpretation by cask vendors. Unfortunately this has lead to confusion on the details. The NRC specifically states in their guidance, " Although insights gained from reviewing the TR submittals form a part of the basis for the staff's position, this interim staff guidance does not approve the TR or its supporting documentation." With this comment it is unclear what parts of the TR (DOE's Topical Report) are okay and what is not. Some these

issues have been resolved through recent interactions with the NRC at meetings sponsored by the Nuclear Energy Institute (NEI). Also Dr. Carlson presented a paper at the Water Reactor Safety Meeting that help clarify some of the issues.[7] This paper goes through an interpretation of what should be in a burnup credit application. This interpretation has not been reviewed by the NRC and may contain concepts that the NRC will not support.

2. LIMITS FOR THE LICENSING BASIS

The first issue for burnup credit is the scope for which burnup credit can be granted. In DOE's Topical Report, a scope was identified in Section 1.3. The ISG-8R1 contains a section entitled "Limits for the Licensing Basis" which covers the same material but adds details for a "loading offset" to allow for extending the enrichment above 4 wt%. The DOE Topical Report contained 6 restrictions to the scope. The following discusses these restrictions:

2.1 BURNUP LIMIT

The NRC states that burnup credit be limited to the "actinide compositions associated with PWR irradiation of UO_2 fuel to an assembly-average burnup value of 40 GWd/MTU or less." This is identical to the restriction in the DOE Topical Report.

2.2 ENRICHMENT LIMIT

DOE's Topical Report had limited the applicability to fuel of nominal enrichment of 4 wt% or less. This restriction was strongly criticized by the industry so the NRC helped by creating a "loading offset." The "loading offset," although quite severe, is of great benefit for casks where a little burnup credit is needed to extend their enrichment limits. For 32 assembly cask designs without control rod credit, the loading offset will be too steep to allow loading much fuel above the low 4 wt% enrichments. The NRC specifies that this restriction can be removed with more chemical assay data or better justification for extrapolation than that contained in the DOE Topical Report. It is recommended that cask vendors wait for the additional chemical assay data.

2.3 BURNABLE ABSORBERS

The DOE Topical Report removed from its scope integral fuel burnable absorbers, such as ZrB_2 coating on the fuel pellet or gadolinia or erbia mixed in the fuel pellet. DOE had no chemical assay data for this type of fuel and choose to delay raising issues with these fuels to the NRC. DOE did, however, include in its methodology how to handle fuel with removable burnable absorbers. Section 5.3.2 of DOE's Topical Report specifically identifies steps needed to conservatively handle fuel with removable burnable absorbers. Unfortunately, DOE did not spend much time clarifying issues with regard to burnable absorbers and the NRC actually believed that fuel with any burnable absorbers were out of scope of DOE's Topical Report. (See last paragraph of "NRC Guidance on Burnup Credit Methods for PWR Spent Fuel in Casks" section of Reference 8.) ISG-8R1 states: "This licensing-basis analysis … should be restricted to intact assemblies that have not used burnable absorbers."

In Reference 8 Dr. Carlson of the NRC identified information needed to allow burnup credit for fuel that used burnable absorbers. The material needed is mainly a physical description and an explanation of operational practices. Since a large fraction of fuel utilizes burnable absorbers, it is recommended that details on the burnable absorbers be given to the NRC and the applicant then take credit for assemblies that have utilized the absorbers. In the case of removable absorbers the position taken by DOE should be sufficient if the NRC has more details. For gadolinium and erbium internal absorbers it can be shown that the negative reactivity due to residual absorber material is always a greater negative reactivity than the positive reactivity due to the spectral hardening. For the coated pellets, analysis is needed to determine an equivalent increase in the soluble boron concentration.

2.4 COOLING TIME

The DOE Topical Report allowed a range of cooling times from 1 to 200 years. ISG-8R1 states, "This licensing-basis analysis should assume an out-of-reactor cooling time of five years." The basis for the NRC not giving credit for more than 5 years of the Pu-241 decay to Am-241 is not clear. There maybe some confusion associated with the impact on end effects since the end effects increase with cooling time. This increase is correctly accounted for in DOE's Topical Report but it seems that is not clear to the NRC. Taking credit for more than five years of cooling is worth a few percent in reactivity or a couple of GWd/MTU. It is recommended that the cask vendor not attempt to challenge the NRC on this issue unless it is determined that it is truly needed.

2.5 MIXED OXIDE FUEL AND DISASSEMBLED FUEL

Both the NRC and DOE excluded this fuel.

3. CODE VALIDATION

A review of the NRC's ISG-8R1 and comments provided since its issue would suggest that following the DOE Topical Report for code validation would be sufficient. The only concern comes from the ISG-8R1 statement:

> "Particular consideration should be given to bias uncertainties arising from the lack of critical experiments that are highly prototypical of spent fuel in a cask."

This appears to be consistent with DOE's position on taking 2% of the fission product margin for criticality validation issues and 1% for computer code adequacy issues. The NRC has been mute on these values selected and also has made no statement on adequacy of the defense of these values. The NRC has had the opportunity to give negative feedback but has not utilized its time to give any feedback on these values. At this time it is recommended to follow DOE's Topical Report.

4. LICENSING-BASIS MODEL ASSUMPTIONS

The NRC's ISG-8R1 and DOE's Topical Report are in general agreement on this topic. However, in recent presentations the NRC may be uncomfortable with the selection of the limiting axial profiles and the lack of treatment of the control rod effects on isotopics.

DOE selected limiting axial burnup profiles from a large database of over three thousand shapes. However, DOE did not present strong arguments justifying that the database contained what would be expected to be the most limiting shapes. The DOE database contained a number of early cores that used inserted control rods for reactivity control. Such operation is extremely rare now. The limiting axial burnup shapes clearly reflect the inserted rods. Since the axial burnup profile is fairly easy to measure, it maybe desirable to show by measurement that the axial treatment is conservative.

DOE covered the control rod effect on isotopic content by use of the fission product margin. It is not clear whether the NRC feels comfortable with this approach. In Reference 8, Dr. Carlson has requested more data on control rod operation. It is recommended that the cask vendor obtain this information for the plants that may utilize the cask.

5. LOADING CURVE

The NRC and DOE appear to be in agreement on format of the loading curve. The only difference is on burnable absorbers and cooling time, which have already been discussed.

6. ASSIGNED BURNUP LOADING VALUE

The DOE Topical Report left a number of issues to be resolved later on the assigned burnup loading value since there would be time in between cask vendors submitting license applications and cask loading to resolve these issues. However, on this issue the NRC was extremely helpful. The NRC states in ISG-8R1:

> "The applicant should describe administrative procedures that should be used by licensees to ensure that the cask will be loaded with fuel that is within the specifications of the approved contents. The administrative procedures should include an assembly measurement that confirms the reactor record assembly burnup. The measurement technique may be calibrated to the reactor records for a representative set of assemblies. For an assembly reactor burnup record to be confirmed, the measurement should provide agreement within a 95 percent confidence interval based on the measurement uncertainty. The assembly burnup value to be used for loading acceptance (termed the assigned burnup loading value) should be the confirmed reactor record value as adjusted by reducing the record value by the combined uncertainties in the records and the measurement."

DOE's Topical Report had specified using the uncertainty of the measurement **or** the reactor records rather than the combined uncertainties of the records and the measurement. It is recommended to statistically combine these uncertainties. This would essentially make the uncertainty the same as that of the measurement device since it is expected to be larger than the uncertainty of the reactor records.

The NRC was particularly helpful in clarifying that the basis for burnup is the reactor record burnup and that the calibration of the measurement device can utilize the reactor records. Both of these issues had received much discussion.

The NRC seems to suggest that the cask vendor be involved in the burnup verification measurement. This was specifically avoided in DOE's approach. It is recommended that the cask vendor involvement be very limited.

VII. ESTIMATE OF ADDITIONAL REACTIVITY MARGIN

In the DOE Topical Report there was a summary section which provided some information on available margin and showed that the available margin exceeded the margin reserved to resolve three final issues: 1) Criticality validation issues (2%), 2) Effect of control rods on isotopics (1% to 3.3%), and 3) Computer code adequacy (1%). It was DOE belief that these issues would be generically resolved by not using fission products. It is clear that NRC did not agree that they are generically resolved and wish to see the margin tally for each cask application. The NRC has pointed out correctly that the fission product worth depends on cask design since there is competition for neutrons between the fission products and the absorbing material added to the cask. The NRC showed significantly less fission product worth using a cask model than that reported by DOE which used an infinite sea (no absorber) model.[8] Using the NRC model, the NRC showed that the three final issues listed above could exceed the available margin by as much as 1.9% for the low enrichment and burnup cases. This has lead to the following requirement as stated in ISG-8R1:

> "The applicant should provide design-specific analyses that estimate the additional reactivity margins available from fission product and actinide nuclides not included in the licensing safety basis. The analysis methods used for determining these estimated reactivity margins should be verified using available experimental data (e.g., isotopic assay data) and computational benchmarks that demonstrate the performance of the applicant's methods in comparison with independent methods and analyses. The Organization for Economic Cooperation and Development Nuclear Energy Agency's Working Group on Burnup Credit provides a source of computational benchmarks that may be considered. The design-specific margins should be evaluated over the full range of initial enrichments and burnups on the burnup credit loading curve(s). The resulting estimated margins should then be assessed against estimates of: (a) any uncertainties not directly evaluated in the modeling or validation processes for actinide-only burnup credit (e.g., k-effective validation uncertainties caused by a lack of critical experiment benchmarks with either actinide compositions that match those in spent fuel or material geometries that represent

the most reactive ends of spent fuel in casks); and (b) any potential nonconservatisms in the models for calculating the licensing-basis actinide inventories (e.g., any outlier assemblies with higher-than-modeled reactivity caused by the use of control rod insertion during burnup)."

Since the list of activities is similar to that performed by DOE in the Topical Report, it seems as though it would be reasonable to follow DOE's approach supplemented by performing the OECD working group benchmarks.

CONCLUSIONS

Although the NRC did not accept DOE's Topical Report on burnup credit, the guidance that the NRC has given is sufficiently similar to DOE's Topical Report that one can estimate that the burnup credit benefits are about the same. It appears that NRC guidance will allow increasing the capacity of canisterized transport casks from 24 assemblies to 32 assemblies.

ACKNOWLEDGEMENTS

This work is a continuation of the work that had been sponsored by DOE for the last ten years. Throughout that period William Lake has done an excellent job at keeping his eye on the prize. Now we have finally made it. Congratulations Bill.

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