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March 14, 2008

Mr. Stewart Brown, Project Manager
Licensing Branch
Division of Spent Fuel Storage and Transportation
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
11555 Rockville Pike
Rockville, MD 20852-2738

Subject: Minutes of the February 21, 2008 MAGNASTOR Draft RAI Part II Teleconference
Docket No. 72-1031 (TAC No. L23764)

Dear Mr. Brown:

NAC International (NAC) hereby submits the subject minutes documenting the discussions and clarifications for each Draft RAI question provided to NAC February 19, 2008 and discussed with the NRC staff February 21, 2008. As discussed during the teleconference, clarification beyond the actual discussion during the teleconference and proposed edits to SAR text are included in the attached document as appropriate with each respective Draft RAI question.

This submittal includes eight copies of this transmittal letter and eight copies of the Attachment 1 – MAGNASTOR Draft RAI Part II, NRC teleconference February 21, 2008. Upon NRC review and approval, the proposed SAR changes will be incorporated into a formal SAR supplement to the MAGNASTOR SAR currently under review.

If you have any questions regarding this submittal, please contact me at 678-328-1274.

Sincerely,

Anthony L. Patko
Director, Licensing
Engineering

Attachment 1 – MAGNASTOR Draft RAI Part II, NRC Teleconference February 21, 2008

ED20080027

NMSS01

Draft RAI-Part II Teleconference
Docket No. 72-1031, (TAC No. L23764)
March 14, 2008

MAGNASTOR Draft RAIs
NRC Teleconference February 21, 2008

Participants

NRC: Meraj Rahimi, Nader Mamish, Larry Campbell, Mike Waters, Mike Call, Zhian Li, Dan Forsyth

NAC: Tom Danner, Holger Pfeifer, Anthony Patko

General Discussion

Meraj Rahimi, acting PM, initiated the conference call to review the second set of Draft RAIs prepared by the technical staff and to introduce the NRC proposed path for resolution of these Draft RAIs.

Nader Mamish summarized the proposed guidance being adopted as the same path presented with the Draft RAI Part I discussion. The proposed path is to have "the licensee include the questions from the teleconference, e-mail, or fax in their docketed response." It is the intent of the call to review each question to assure that the applicant has a clear understanding of the question and not to have an extensive technical discussion of the issue. Following this modified agenda for the teleconference it is the intent to use the same categorization adopted for the Draft RAI Part I format. Each draft RAI will be categorized as a respective Category 1, 2 or 3. Category 1 represents that the teleconference discussion has resolved the question; no additional information is required. Category 2 indicates minor SAR text edit is required to close the issue. Category 3 represents a staff issue that requires additional information from NAC to resolve the NRC question that may, or may not require a change to the SAR text.

Following this brief introduction, the Draft RAI's were addressed in order of importance as categorized by the review staff. The following summary is provided in the order of the organized RAI for clarity and consistency and is not representative of the actual sequence of the discussion.

The format adopted for each question is 1) Statement of the RAI, 2) Summary of Technical Discussion, 3) Proposed Resolution, Category, and 4) Draft SAR Text Change.

The following table summarizes the Draft RAI Part II disposition relative to the NAC proposed Category evaluation.

Chapter	**# of Draft RAI's**	**Category**		
		1	**2**	**3**
5	13	1	11	1
9	1			1
13	2	1		1
Total	**16**	**2**	**11**	**3**

Chapter 5.0 Shielding Evaluation

Section 5.1 Cask Shielding Discussion and Dose Results

5.1 Draft RAI

Provide information and justification on and the source term evaluation results of the fuel assemblies that contain axial end unenriched uranium blankets.

The applicant provides in Chapter 1 of this SAR a general description of the MAGNASTOR. In Sections 1.4 and 2.2, the SAR states that allowable contents include fuel assemblies containing natural uranium axial blankets. The staff, however, was unable to find from the SAR any further information on this type of fuel assemblies and corresponding shielding evaluations with these contents.

This information is needed for the staff to determine if MAGNASTOR system design and operation the meet the shielding safety requirements pursuant to 10 CFR 72.104, 72.126, 72.128, and10 CFR 20.1201.

Summary of Technical Discussion

Natural uranium (unenriched) blankets are typically employed in BWR/4-6 reactor core fuel assembly designs and are also implemented in some PWR fuel assembly designs. The source and shielding evaluations in Chapter 5 of the SAR rely on average initial enrichments and average assembly burnup to determine allowed cool time limits, see Section 5 paragraph 3, page 5-1 "Minimum cool times prior to fuel transfer and storage are specified as a function of minimum assembly average fuel enrichment and maximum assembly average burnup (MWd/MTU)." Assembly average burnup is defined in the terminology section to encompass all UO_2 material, this includes by definition the unenriched regions. While not defined in the SAR, the maximum assembly average burnup is intended to similarly correspond to a value calculated from the entire fuel region (UO_2), including axial blankets.

As the blanket regions are accounted for in the overall source production by inclusion of its mass (kg UO_2), burnup, and initial enrichment, the discussion on the presence of the blankets in the shielding chapter are limited to potential effects on the burnup shape. As discussed in the response to draft RAI 5-8, BWR blankets (unenriched) are directly accounted for in the data sets comprising the burnup curve. The PWR data set used by NAC in establishing its burnup profile did not specifically address low enriched (or unenriched) blankets in PWRs. YAEC-1937 [R. J. Cacciapouti and S. Van Volkinburg, "Axial Burnup Profile Database for Pressurized Water Reactors," YAEC-1937, Yankee Atomic Electric Company (May 1997)] contains over 3000 profiles including zoned (blanketed) assemblies. This database was obtained from the Radiation Safety Information Computational Center at Oak Ridge National Laboratory as DLC-201. YAEC-1937 is the principal reference for fuel profiles in NUREG/CR-6801 ["Recommendations for Addressing Axial Burnup in PWR Burnup Credit Analyses, March 2003]. Figure 5.1-1 displays the NAC profile (obtained for assembly burnups over 30 GWd/MTU) in conjunction

with the 30-35 GWd/MTU data from YAEC-1937 that includes blanket assemblies in the dataset. As shown the profiles match well. Discussions on the effect of variation in burnup on the profile shape are included in the response to Draft RAI 5-7 (and 5-8).

Proposed Resolution
Category 2

The SAR terminology section in Section 1 and definitions in Section 13 will be modified to specify the definition of assembly initial enrichment. Assembly average enrichment and average burnup definitions will include specific references to axial blankets. Text is added in Section 5.3 to clarify the origin and applicability of the burnup curves to blanketed fuel. Also included in Section 5.3 of the SAR will be the RAI response Figure 5.1-1. Both text and figure are included in the RAI 5-8 "Draft SAR Text Change" section.

Draft SAR Text Change

Chapter 5 Changes

Section 5.3 is modified to include PWR and BWR axial blanket discussions. The text changes are included in the Draft RAI 5-8 pages.

Tech Spec and Chapter 1 Changes

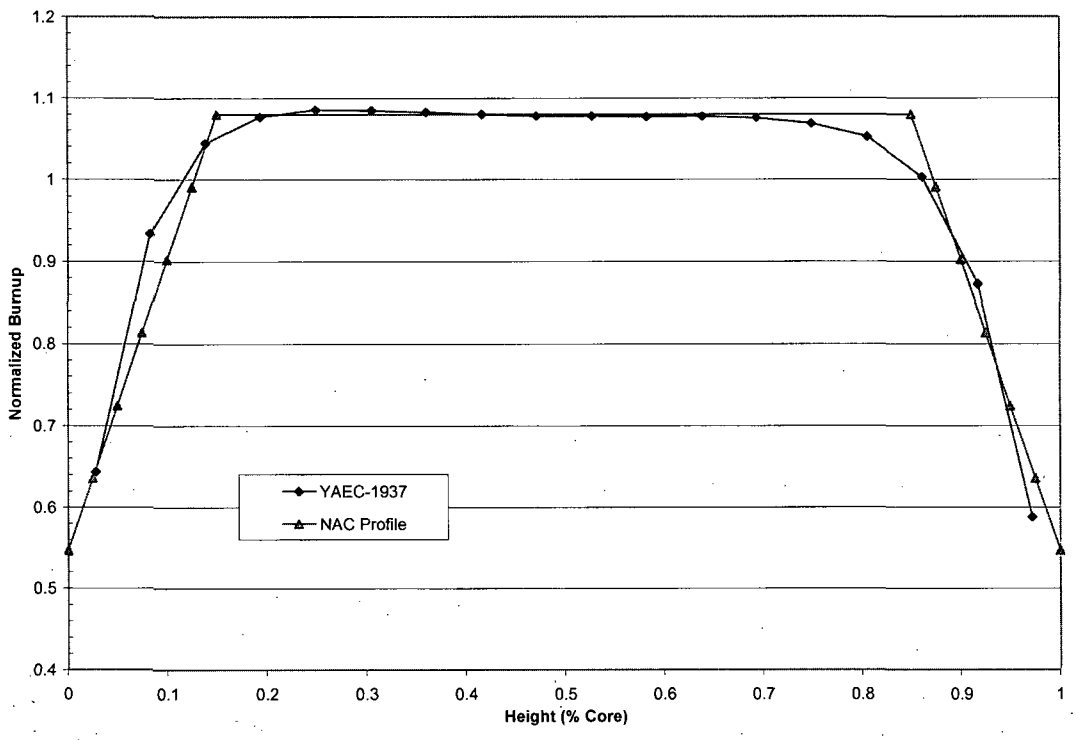
Add definition:

Assembly Average Fuel Enrichment –
Value calculated by averaging the ^{235}U wt % enrichment over the entire fuel region (UO_2) of an individual fuel assembly – including axial blankets if present.

Modify definition

Assembly Average Burnup
Value calculated by averaging the burnup over the entire fuel region (UO_2) of an individual fuel assembly – ***including axial blankets if present.***

Figure 5.1-1 YAEC-1937 versus NAC Burnup Profile for 30-35 GWd/MTU PWR Fuel Assemblies



Section 5.1.1 Transfer Cask Shielding Discussion and Dose Results

5-2 Draft RAI

Clarify if the transfer cask dose calculations and the accumulate dose estimates of the various TSC operations rely on the 6-inch weld platform to provide sufficient shielding. If so, update the shielding evaluation and radiation protection chapters of the SAR to clearly state this assumption.

The applicant states on page 5.1-1 of the SAR that all dose rate evaluations assume that the majority of the operations, in particular closure lid welding, are performed under water with a weld platform which provides a 6-in auxiliary shield. However, it is not clear what operations are performed under the water. It is not clear if the shielding analyses and occupational exposure estimates in Chapter 9 assume the transfer cask is flooded and if a 6-inch welding platform is necessary shielding.

This information is needed for the staff to determine if MAGNASTOR system design and operation the meet the shielding safety requirements pursuant to 10 CFR 72.104, 72.126, 72.128, and 10 CFR 20.1201.

Summary of Technical Discussion

As stated on page 5.1-1 of the SAR, all transfer cask shielding evaluations are based on the dry canister with weld shield.

> "The three-dimensional transfer cask shielding analysis provides a complete, nonhomogenized representation of the transfer cask and TSC structure. The model assumes the following TSC/transfer cask configuration for all dose rate evaluations.
>
> • 6-in auxiliary weld shield
>
> Closure lid weld operations are typically performed with an automated weld system that is mounted on a weld platform. The presence of this platform provides significant auxiliary shielding during the TSC closure operation."

Per Chapter 9 operating procedures, the canister welding is performed with the canister filled with water, not necessarily with the cask/canister under water (partially submerged). Occupational exposures in Chapter 11 are based on the dose rates determined in Chapter 5 and are therefore based on the dry canister with weld shield. Chapter 9 operating procedures, Section 9.1.1, Step 38, provides for the installation of the "welding system, including supplemental shielding." The quantity of supplemental shielding optionally added on the system is an ALARA item with plant specific requirements affecting the quantity of, or need for, the supplemental shielding.

Occupational exposures reported by NAC cask users have consistently been lower than those reported in Chapter 11. In particular, users that dry and seal the canister while the canister is still partially submerged have consistently reported exposures below 100 mrem for the entire loading sequence performed with experienced staff. These actual plant operational dose results demonstrate that cask radial dose rates are occupational dose drivers, and that the need for supplemental axial shielding should be evaluated as part of the radiation protection program as specified in Appendix A Section 5.5 of the SAR.

Proposed Resolution
Category 2

Revise Chapter 11 to specify that exposures are based on a dry canister cavity with auxiliary shield and conservative heat load dose rates and that per Technical Specification 5.5 (Chapter 13 Appendix A), the system user must implement an ALARA program that includes reviewing the need for and quantity of supplemental shielding applied.

Draft SAR Text Change

Section 11, page 11-1 is revised as follows:

"MAGNASTOR is provided in PWR and BWR fuel assembly configurations. The PWR system is designed to store up to 37 PWR spent fuel assemblies and associated nonfuel hardware. The BWR system is designed to store up to 87 BWR spent fuel assemblies with or without zirconium-based alloy channels. The radiation protection features and analysis presented in this chapter apply to both fuel assembly configurations. The estimated exposures for operations and storage are based on the PWR or BWR contents that result in the highest dose rates. ***Transfer cask exposures are based on the cask configuration documented in Section 5.1.1 and as such rely on a dry canister cavity with supplemental (weld) shield in place."***

5.1.2 Concrete Cask Shielding Discussion and Dose Results

Section 5.2 Source Specification

5-3 Draft RAI

Justify the conclusion that SAS2H/44GROUPNDF5 sequence is applicable to the spent fuel with 62.5 GWD/MTU burnup.

On page 5.2-1 of the SAR, the applicant states: "Open literature validations of the SCALE SAS2H/44 group library versus experimental data do not extend to the system allowable burnup of 62.5 GWD/MTU peak averaged rod. Studies performed in NUREG/CR-6701 (Appendix B) [36] indicate no analysis trends in the system sensitivity for LWR SAS2H/44GROUPNDF5 evaluations up to burnup of 75 GWD/MTU. As such, the SAS2H/44GROUPNDF5 sequence is applicable to high burnup fuel evaluated." The staff however was unable to find this statement in NUREG/CR-6701. Also the staff finds it is difficult to draw the conclusion from the statements. The staff's understanding is that no analysis trends simply mean there is no conclusion. It does not provide indication to either direction. This information is needed for the staff to perform confirmatory analyses for the shielding safety requirements pursuant to 10 CFR 72.104, 72.126, and 72.128.

Summary of Technical Discussion

NAC primarily relied on the third paragraph of Section 5.2.1 for the applicability of the SAS2H analysis to LWR fuel with assembly average burnup up to 60 GWd/MTU. The paragraph states the following.

> "The 44-group library (44GROUPNDF5) is composed primarily of ENDF/B-V cross-sections with ENDF/B-VI data for a limited number of isotopes (e.g., ^{154}Eu and ^{155}Eu). The cross-section set is collapsed using an LWR spectrum. References 31 through 35 contain extensive SAS2H validation for PWR burnups up to 47 GWd/MTU and BWR burnups up to 57 GWd/MTU. As indicated in the reference documentation, the combination of the SCALE 4.4 SAS2H sequence and the 44 GROUPNDF5 cross-section library is applicable to LWR fuel assembly source term generation for high burnup fuel."

As data is considered up to 57 GWd/MTU an extrapolation to the 60 GWd/MTU requested burnup is considered by NAC to be reasonable.

NUREG/CR-6701 was considered only in the context of providing trending information for the extrapolation and general behavior of the code. While NAC agrees that the main body of the reference document primarily discusses currently available data and proposes future paths of study, Appendix A of the document applies sensitivity methods to determine "the sensitivities of the input variables and data parameters on the calculated quantities of

applications of interest." In Section A.6.1 for example, the sensitivity of ^{251}Am (a significant producer of decay heat) is evaluated at a sensitivity parameter of 0.98 at 75 GWd/MTU and 1.0 at the beginning of the cycle. This indicates that while the relative sensitivity of the parameter is high, its accuracy is not significantly affected by the burnup increase. Another example is Section A.6.3 in that fission and (n,2n) cross sections for various U and Pu isotopes show no significant change in sensitivity over 40 GWd/MTU. Overall, the discussions in Appendix A and B of NUREG/CR6701 indicate that within the range of requested burnup SAS2H will provide acceptable results.

The review staff states that "The staff's understanding is that no analysis trends simply mean there is no conclusion." An analysis of independent parameter versus calculated quantity may lead to one of two conclusions, either there is a trend in the data (i.e., there is a quantifiable effect that a change in the independent parameter has on the calculated quantity) or there is no trend (i.e., changes in the independent parameter have no consistent/quantifiable effect on the calculated quantity). "No trend" is therefore a possible conclusion of the data analysis.

Proposed Resolution
Category 2

The quoted paragraph was revised as part of the RAI 5-4 response. With the explanation shown above no changes to the SAR text are considered necessary with the exception of adding Appendix A of the NUREG into the discussion.

Draft SAR Text Change

Section 5.2, page 5.2-1 is revised as follows:

"Studies performed in NUREG/CR-6701 (Appendix ***A and*** B) [36] indicate no analysis trends in the system sensitivity for LWR SAS2H/44GROUP"

5-4 Draft RAI

Clarify the definitions of the terms "Max Assembly Average Burnup" and "Peak Average Rod Burnup" and how these parameters are used in the spent nuclear fuel radiation source term calculations.

On pages 2.2-6, 2.2-7, Tables 2.2-1 and 2.2-2, of the SAR, the applicant introduced two terms on the fuel assembly burnup. One is the Max Assembly Average Burnup and the other is Average Rod Burnup. It is, however, not clear how these terms are related to and used in radiation shielding calculations.

This information is needed for the staff to determine if the MAGNASTOR system design meets the shielding safety requirements pursuant to 10 CFR 72.104, 72.126, 72.128, 20.1201, and 20.1301.

Summary of Technical Discussion

Both Chapter 1, Section 1.1 Terminology and Chapter 13. Appendix A. Section 1.1 Definitions provide definition for assembly average burnup and peak average rod burnup. The definition from the terminology section in Chapter 1 (as modified by Draft RAI 5-1) is as follows:

"Assembly Average Burnup

Value calculated by averaging the burnup over the entire fuel region (UO_2) of an individual fuel assembly – ***including axial blankets if present.***

Peak Average Rod Burnup

Value calculated by averaging the burnup in any rod over the length of the rod, then using the highest burnup calculated as the peak average rod burnup."

Chapter 5 relies on the assembly average burnup as input into the radiation shielding analysis. Peak average rod burnup is not employed in the shielding evaluation section and is included as a limitation in the package due to material (fuel rod clad) constraints. Technical specification limits are applied to the maximum assembly average burnup, and initial enrichments, to determine minimum allowed cool time to meet heat load limits (and conform to the shielding evaluation).

Proposed Resolution
Category 2

Modify Section 5.2 text to clarify that the peak rod burnup is included as a materials limit separate from any shielding evaluations that rely on assembly average burnup as a control characteristic. Clarify in Section 5.2 that assembly average burnup is employed in all source generation and subsequent shielding evaluations (after application of the axial source profile).

Further, revise Section 5.4 to clarify how the assembly average burnup source terms are adjusted by the peaking factor to determine accurate source distribution and magnitude.

Draft SAR Text Change

Section 5.2, page 5.2-1 is revised as follows:

"……

Open literature validations of the SCALE SAS2H/44 group library versus experimental data do not extend to the system allowable ***assembly average*** burnup of ***60*** GWd/MTU. Studies performed in NUREG/CR-6701 (Appendix B) [36] indicate no analysis trends in system sensitivity for LWR SAS2H/44GROUPNDF5 evaluations up to a burnup of 75 GWd/MTU. As such, the SAS2H/44GROUPNDF5 sequence is applicable to the high burnup fuel evaluated.

Source terms are generated on an assembly average burnup basis using SAS2H and are adjusted to reflect the burnup profile as discussed in Sections 5.3 and 5.4. Peak average rod burnup limitations are the result of limited available data on the material properties of high burnup fuel cladding and its behavior during storage conditions. The peak average rod burnup is only listed in this section to demonstrate that available validation data on SAS2H of burnups up to 57 GWd/MTU, and trending in NUREG/CR-6701 up to 75 GWd/MTU, are applicable to the assemblies evaluated.

The hardware activation is calculated by light element transmutation using …."

[Further draft clarification changes on assembly profiles are included in the Draft RAI 5-3 and RAI 5-7 through 5-9 responses including SAR Section 5.4.]

Section 5.2.1 Gamma Source

Section 5.2.2 Neutron Source

5-5 Draft RAI

Provide neutron dose rate for flooded cask.

On page 5.2-4 of the SAR, the applicant states that the keff value used to calculate the subcritical neutron multiplication is 0.4 for the dry cask. It is not clear however what the neutron dose rate is calculated for a partially flooded TSC in the spent fuel pool at the moment the loaded TSC is lifted out of the spent fuel pool.

This information is needed for the staff to determine if the MAGNASTOR system design meets the shielding safety requirements pursuant to 10 CFR 72.104, 72.126, 72.128, 20.1201, and 20.1301.

Summary of Technical Discussion

As stated in Section 5.1.1, "Transfer Cask Shielding Discussion and Dose Results," under the first bulleted item, the three-dimensional transfer cask shielding analysis applied a dry canister cavity to determine dose rates. A wet canister system, including partial flooding, was not evaluated. The bullet indicates that dry canister evaluations are conservative without further qualifications. A flooded canister, while increasing subcritical multiplication as a function of $1/(1-k_{eff})$, includes significant neutron shielding inherent in the water contained within the canister cavity. The water provides sufficient shielding in the radial and axial direction to offset the increased neutron source.

While no specific evaluations were performed for the MAGNASTOR system, similar NAC cask designs have been evaluated in both dry and wet canister configurations. For example, design calculations for the NAC-UMS system demonstrated a 50% increase in the radial dose rate for the dry configuration versus wet. NAC-MPC calculated dose rates doubled when going from a wet to dry configuration. Axial dose rate comparisons can be made from calculated cask bottom dose rates as top dose rates are influenced by the variation in shield geometries applied in the wet and dry configurations (the systems have a dual lid design where the wet configuration is applied with the shield lid, while dry dose rates are determined with the structural lid in place). Calculated bottom dose rates for the NAC-UMS system were 50% higher for the dry system than the wet system and over a factor of four higher for the NAC-MPC system.

Proposed Resolution
Category 2

Revise Section 5.1.1, page 5.1-1, to provide additional explanations as to why the dry system is bounding considering the potential subcritical multiplication neutron source increase associated with a flooded (wet) active fuel region.

Draft SAR Text Change

Section 5.1.1, page 5.1-1 is revised as follows:

"

- Dry canister cavity
  The majority of the TSC operations, in particular closure lid welding, are performed with the TSC cavity filled with water. Evaluating a dry canister cavity is conservative. Note that the water filling the TSC/transfer cask annulus between the inflatable seals is modeled.
  Transfer cask dose rates from a wet canister, while containing an increased neutron source due to a higher subcritical multiplication resulting from a higher k_{eff} are lower than those of the dry system due to the additional radiation shielding provided by the water within and surrounding the source region. Evaluations of similar transfer cask systems, in particular the NAC-UMS and NAC-MPC, have demonstrated that dry system dose rates are significantly (50+%) higher than those of the wet system."

Section 5.2.3 Bounding Gamma and Neutron Spectrum

5-6 Draft RAI

Check and correct if necessary the inconsistency in the Table 5.2.3-3 and Table 5.2.3-5 and text on page 5.2-4 of the SAR that reference these tables.

On page 5.2-4 of the SAR, the applicant states: "BWR fuel assembly source spectra for the cases producing the maximum radial dose rates are shown in Table 5.2.3-6 for gamma source and Table 5.2.3-7 for neutron source." In fact, Table 5.2.3-3 and Table 5.2.3-5 of the SAR provide the □ and neutron spectra respectively. There appears to be a discrepancy between these statements and the titles of these tables.

This information is needed for the staff to determine if the MAGNASTOR system design meets the shielding safety requirements pursuant to 10 CFR 72.104, 72.126, 72.128, 20.1201, and 20.1301.

Summary of Technical Discussion

NAC reviewed the SAR as submitted and determined that the correct pages were included in the copy provided to the NRC for approval. Page 5.2-4 of the SAR states:

> "BWR fuel assembly source spectra for the cases producing the maximum radial dose rates are shown in Table 5.2.3-6 for the gamma source and in Table 5.2.3-7 for the neutron source."

Table 5.2.3-6, page 5.2-9, is titled "Gamma Source Spectrum – Maximum Radial Dose Configuration," while Table 5.2.3-7, page 5.2-10, contains "Neutron Source Spectrum – Maximum Radial Dose Configuration." The cross-reference on page 5.2-4, therefore, correctly identifies the relevant tables.

Proposed Resolution
Category 1

The pages as provided are correct. NRC review staff should confirm NAC review of the current SAR text based on information provided herein.

Draft SAR Text Change

SAR text changes are not required.

Section 5.3 Axial Burnup Profile

5-7 Draft RAI

Justify that the peaking factors 1.08 and 1.22 for PWR and BWR fuel assemblies, respectively, are applicable for all of the fuels specified in Section 2.2 of the SAR.

Section 5.3 of the SAR states that an axial uniform peaking factor is used in calculating the source term. The peaking factors are 1.08 for PWR assemblies based on calculated data from Seabrook and Yankee plants and measured Turkey Point gamma data. The peaking factor is 1.22 for BWR assemblies based on calculated data from Washington Public Power BWR/4-6. Studies in NUREG/CR-6801, which used a much broader spent fuel assembly database, indicate larger peaking factors and more complex burnup profiles for low burnup fuels.

This information is needed for the staff to determine if the MAGNASTOR system design meets the shielding safety requirements pursuant to 10 CFR 72.104, 72.126, 72.128, 20.1201, and 20.1301.

Summary of Technical Discussion

As discussed in the response to draft RAI 5-8, lower burnup fuel assemblies, while displaying larger peaking factors than those obtained from >30 GWd/MTU fuel assemblies, produce significantly lower dose rates (at a fixed profile). The dose decrease is significantly larger than the peaking factor increase. Note that site dose rates (10 CFR 72.104 limit on storage systems) is driven by system gamma dose rates which are proportional to the average fuel source which decreases by 15% going from 30 GWd/MTU to 25 GWd/MTU and by over 30% shifting from 30 GWd/MTU to 20 GWd/MTU.

NUREG/CR-6801 contains a significantly larger cross section of burnup profiles, primarily based on YAEC-1937 data. The profile comparison in draft RAI 5-8 documents the acceptability of the NAC shapes against the larger data set.

The technical discussion in the RAI 5-8, as summarized above, justifies the use of 1.08 and 1.22 peaking factors and profiles used in the NAC SAR.

Proposed Resolution
Category 2

SAR modifications are made in Section 5-3 to justify the use of the 1.08 and 1.22 peaking factors and burnup profiles.

Draft SAR Text Change

See RAI 5-8.

5-8 Draft RAI

Justify the conclusion in Section 5.3 that "fuel burned in excess of 30 GWD/MTU produces the maximum dose rates."

The basis for this statement is not clear and how it applies to the subsequent shielding analyses.

This information is needed for the staff to determine if the MAGNASTOR system design meets the shielding safety requirements pursuant to 10 CFR 72.104, 72.126, 72.128, 20.1201, and 20.1301.

Summary of Technical Discussion

Section 5.3, "Axial Burnup Profile," begins with "Fuel burned in excess of 30 GWd/MTU produces the maximum dose rates as shown in Section 5.6." The statement was included to support the use of a burnup profile developed from fuel assembly data at burnups above 30 GWd/MTU. The dose rates in Section 5.6 are based on Sections 5.8.3 (PWR) and 5.8.4 (BWR) shielding results summarized in Section 5.1, Table 5.1.3-1 through 5.1.3-3. As shown in Table 5.1.3-3, maximum dose rates are obtained from fuel burned in excess of 30 GWd/MTU (e.g., radial concrete cask dose rates are maximized at 32.5 GWd/MTU, 4 year cooled). While fuel assemblies with low (<30 GWd/MTU) assembly average burnup may contain higher burnup profile peaks (e.g., NUREG/CR-6801 lists a peak of 1.14 in the 26 to 30 GWd/MTU range for PWR fuels) fuel sources at the lower burnups are reduced more than the potential increase in peaking factor. Figures 5.3-3 and 5.3-4 (new SAR figures) contain cask midplane and average dose rate plots for sample PWR and BWR fuel types (14b and 09a which produce bounding radial concrete and transfer cask dose rates) to demonstrate the reduction in dose rate at lower burnups (data is for the 1.08 PWR or 1.22 BWR peak profile) and a fixed system heat load (a 4 year minimum cool time results in reduced heat loads for low burnup material). Each data point with cool times over 4 years represents the minimum cool time allowed to meet the system heat load limit. As demonstrated in the figures, a substantially higher peaking factor, such as those of low burnup fuel shown in the profile summary of Figure 5.3-6, would not result in increases in dose rates above the 30 GWd/MTU based values. This justifies the use of the 30 GWd/MTU and above burnup data for the limiting profile. Figure 5.3-6 is based on YAEC-1937 data discussed in draft RAI 5-1.

Proposed Resolution
Category 2

The SAR text in Section 5.3 is revised to identify the justification for the statement. The statement is rewritten to clarify that higher burnup fuels produce bounding dose rates and include supporting justification in terms of the dose rate plots provided in the technical discussion.

Draft SAR Text Change

Section 5.3, page 5.3.1 is revised as follows:

> [Note that SAR changes in this section also include modified text to clarify axial blankets and burnup shape effect (RAI 5-1) as well as providing additional references used in the BWR profile. Only WPP data had been previously reflected in the SAR write-up. No changes to the burnup profile are made with this added clarification.]

The axial burnup profile changes as fuel burnup progresses from initial in-core loading (0 GWd/MTU) to the maximum burnup requested (60 GWd/MTU). For PWR fuel assemblies, maximum burnup peaking occurs in the range of 10 to 15 GWd/MTU with a peak of approximately 1.25. The burnup profile peak then decreases as burnup increases to the 30 GWd/MTU range after which the peak remains relatively constant. For BWR fuel assemblies, similar peaking occurs early during depletion with a bottom peak near 1.35 in the range of 10-20 GWd/MTU. The BWR peak burnup ratio then decreases to the 1.22 peak specified below. Dose calculations on both transfer and storage systems summarized in Section 5.1 demonstrate that, at a fixed burnup profile, fuel assemblies burned in excess of 30 GWd/MTU produce maximum dose rates. For a fixed burnup profile, Figure 5.3-3 (storage cask) and Figure 5.3-4 (transfer cask) illustrate the dose rate increase as a function of burnup that offsets any potential increase in burnup peak at lower burnup levels.

Figure 5.3-6 contains YAEC (YAEC-1937, RSICC Document DLC-201) compiled PWR burnup profiles at 5 GWd/MTU increments showing low burnup fuel having a higher peak. Peaking is less than 10% higher for the low burnup material, which is a smaller increase than the dose decreases plotted in Figure 5.3-3 and Figure 5.3-4 for the lower burnup fuels. The following discussion therefore describes the burnup profile for fuel burned in excess of 30 GWd/MTU. The 30 GWd/MTU derived profile is applied in the shielding evaluations summarized in Sections 5.1 and 5.6 and detailed in Section 5.8.

Fuel burned in excess of 30 GWd/MTU produces the maximum dose rates as shown in Section 5.6. For PWR fuel, an enveloping axial burnup profile with a 1.08 uniform peaking factor is justified on the basis of calculated PWR data from Seabrook Station and Maine Yankee and from measured Turkey Point gamma data [13,14,15,16,17]. This normalized enveloping shape is shown in Figure 5.3-1. A uniform burnup peaking factor of 1.08 is applied between 15% and 85% of core height. Above and below these elevations, the relative burnup/decay heat decreases linearly to 0.547 at the top and bottom of the active fuel region.

For BWR fuel, an enveloping burnup profile with a 1.22 maximum peaking factor can be justified on the basis of calculated BWR ***burnup profile*** data from ***eight cycles of*** Washington

Public Power (WPP) BWR/4-6 data [18]. This normalized enveloping shape is shown in Figure 5.3-2. Uniform peaking factors of 1.22 and 1.18 are applied from 15% to 55% and from 55% to 80% of core height, respectively. Above and below these elevations, the burnup profile decreases linearly to 0.043 at the top and bottom of the active fuel region. ***This profile bounds the burnup peaks listed in Vermont Yankee and Takoi 2 BWR nuclear power station burnup curves, demonstrating that the detailed information from WPP represents typical BWR operational data and may be used as generic licensing basis.***

PWR and BWR fuel assemblies may contain axial unenriched end regions (blankets). In particular, BWR/4-6 type reactor assemblies are typically designed with 6 inch unenriched axial blankets at the top and bottom of the fuel region. The BWR dataset employed in the calculation of the bounding burnup profile includes axial end-blankets and is therefore directly applicable to the MAGNASTOR contents. PWR information that constructed the PWR curve did not contain blanketed fuel. To demonstrate acceptability of the PWR profile to blanketed fuel, NAC compared the profile in Figure 5.3-1 to the YAEC-1937 [R. J. Cacciapouti and S. Van Volkinburg, "Axial Burnup Profile Database for Pressurized Water Reactors," YAEC-1937, Yankee Atomic Electric Company (May 1997)] profile for assemblies in the range of 30 to 35 GWd/MTU. The YAEC profile includes both blanketed and non-blanketed fuel assemblies. As seen in Figure 5.3-5, the profiles match well demonstrating acceptability of the chosen profile across the range of PWR fuel assembly types.

Figure 5.3-3 Average and Midplane Storage Cask Dose Rates as a Function of Burnup (Fixed Heat Load – 4 Year Minimum Cool Time))

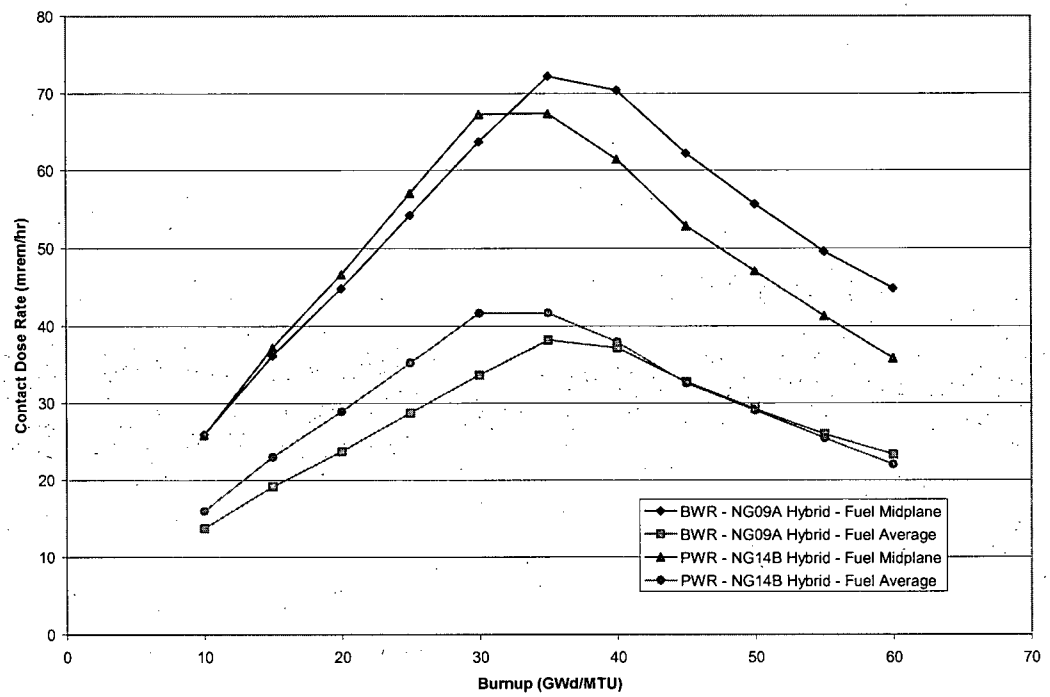


Figure 5.3-4 Average and Midplane Transfer Cask Dose Rates as a Function of Burnup (Fixed Heat Load - 4 Year Minimum Cool Time)

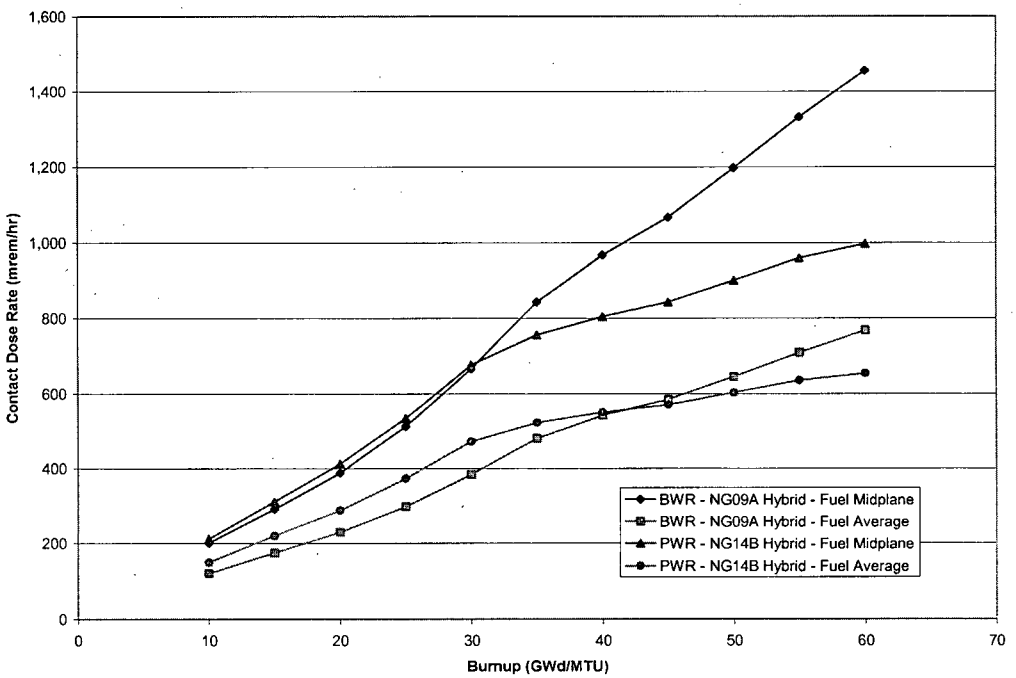
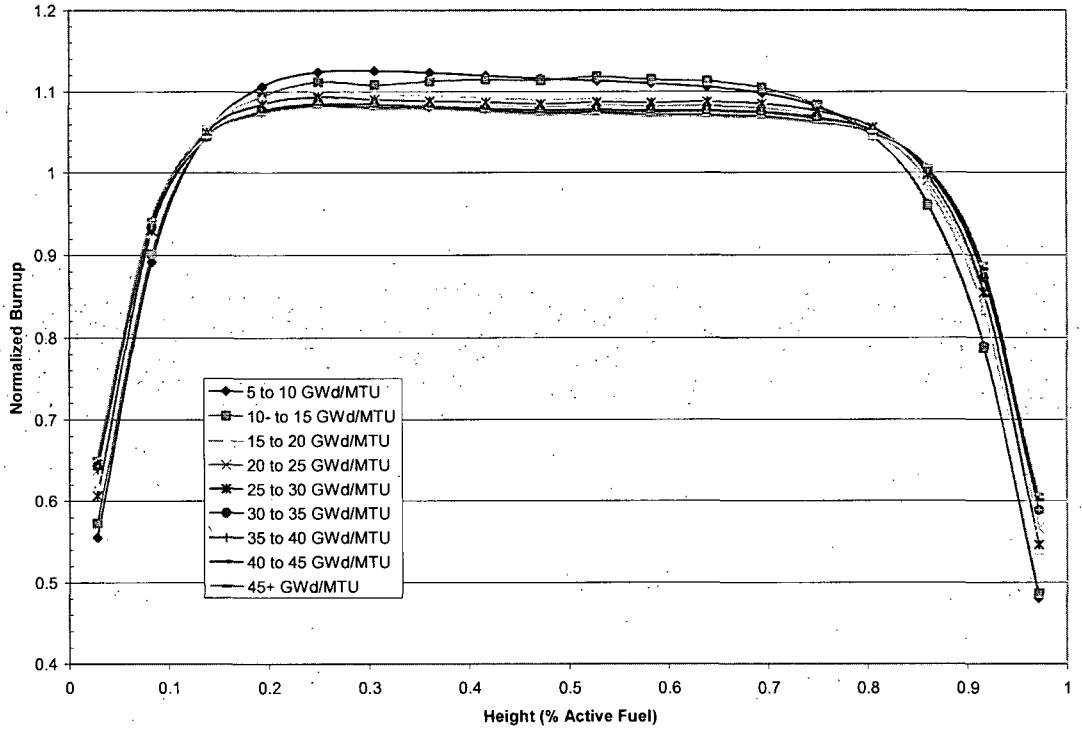


Figure 5.3-5 Normalized Burnup Profiles from YAEC-1937 (Grouped in 5 GWd/MTU Bins)



Section 5.4 Axial Source Profile

5-9 <u>Draft RAI</u>

(a) Update the SAR to include discussion of the technical basis for the S~Bb relationship and the scaling factor equation described in Section 5.4. Clearly identify how these equations, scale factors, and burnup profiles are applied in the shielding calculations.

(b) Provide detailed information on how the pre-calculated transmission and reflection data are determined and how the Monte Carlo technique is used to integrate over the source direction and energy to determine the dose rate at a given location.

(c) Check the consistency and clearly define the terms used in the equation.

(d) Justify that one active fuel zone can represent the source term of entire fuel region of a spent fuel assembly. Provide discussion on the adequacy of using one active fuel zone to represent the source term of entire fuel region of a spent fuel assembly, particularly for fuels with low burnup or unenriched uranium blankets.

(e) Provide explicit definition of the term "cask self-shielding." Provide technical (including theoretical) basis for not tracking the particles that hit the cask between the source and the detector. Justify the assertion that the radiations emitted from the surface of one cask and subsequently hit an adjacent cask will not have a significant contribution to the site boundary dose rate because of the thickness of the cask concrete.

Section 5.4 provides two equations that relate the radiation source term to the fuel assembly burnup. The SAR does not provide a technical basis or discuss its derivation, or specify how this equation is applied to the source terms used in the shielding evaluations. The definitions of the parameters are not clear and may contain errors. For example, "a" is defined but not used and parameter "b" is used without definition. It is not clear how these are applied to the subsequent shielding analyses.

On page 5.5-1 of the SAR, the applicant states that the radiations emitted from the surface of one cask and subsequently hit an adjacent cask will not have a significant contribution to the site boundary dose rate given the thickness of the concrete. The staff, however, finds that this assert underestimates the scattering of concrete surfaces. As a matter of fact, scattering from ground and other hard surfaces may make up a significant contribution to the points/areas of the interest that are far away from the radiation sources. All major dose rate assessment computer codes such as MCNP, SKYSHINE, and RADTRAN, treat concrete media explicitly in their modeling.

This information is needed for the staff to determine if the MAGNASTOR system design meets the shielding safety requirements pursuant to 10 CFR 72.104, 72.126, 72.128, 20.1201, and 20.1301.

Summary of Technical Discussion

a.) The correlation of neutron source strength versus burnup is based on SAS2H (ORIGEN-S) calculated source neutron source magnitudes at various burnup levels fit to a general exponential fit of $S \sim aB^b$, where a is an arbitrary constant and b is the exponent required to match the neutron source to burnup data ("b" value of 4.22). Gamma source is directly proportional burnup resulting in a "b" value of 1.0. SAR text was incorrectly editorially changed to use and to refer to the variable "a" as the exponent.

The equation is used to integrate the neutron profile in Figure 5.4-1 and 5.4-2 to arrive at the neutron scaling factor of 1.127 (PWR) and 1.585 (BWR). The integration is shown below for PWR and BWR profiles.

Axial Burnup and Source Profiles - PWR							
% Core Height	**Burnup Profile**	**Photon Source**	**Neutron Source**	**Photon Interval**	**Neutron Interval**	**Photon Weight**	**Neutron Weight**
0.00%	0.5470	0.5470	7.84E-02				
2.50%	0.6358	0.6358	1.48E-01	5.91E-01	1.13E-01	1.48E-02	2.83E-03
5.00%	0.7247	0.7247	2.57E-01	6.80E-01	2.02E-01	1.70E-02	5.06E-03
7.50%	0.8135	0.8135	4.19E-01	7.69E-01	3.38E-01	1.92E-02	8.44E-03
10.00%	0.9023	0.9023	6.48E-01	8.58E-01	5.33E-01	2.14E-02	1.33E-02
12.50%	0.9912	0.9912	9.63E-01	9.47E-01	8.06E-01	2.37E-02	2.01E-02
15.00%	1.0800	1.0800	1.38E+00	1.04E+00	1.17E+00	2.59E-02	2.93E-02
85.00%	1.0800	1.0800	1.38E+00	1.08E+00	1.38E+00	7.56E-01	9.69E-01
87.50%	0.9912	0.9912	9.63E-01	1.04E+00	1.17E+00	2.59E-02	2.93E-02
90.00%	0.9023	0.9023	6.48E-01	9.47E-01	8.06E-01	2.37E-02	2.01E-02
92.50%	0.8135	0.8135	4.19E-01	8.58E-01	5.33E-01	2.14E-02	1.33E-02
95.00%	0.7247	0.7247	2.57E-01	7.69E-01	3.38E-01	1.92E-02	8.44E-03
97.50%	0.6358	0.6358	1.48E-01	6.80E-01	2.02E-01	1.70E-02	5.06E-03
100.00%	0.5470	0.5470	7.84E-02	5.91E-01	1.13E-01	1.48E-02	2.83E-03
Average						1.000	1.127

Axial Burnup and Source Profiles - BWR							
% Core Height	Burnup Profile	Photon Source	Neutron Source	Photon Interval	Neutron Interval	Burnup Weight	Neutron Weight
0.00%	4.30E-02	4.30E-02	1.71E-06				
2.50%	2.39E-01	2.39E-01	2.39E-03	1.41E-01	1.20E-03	3.53E-03	2.99E-05
5.00%	4.35E-01	4.35E-01	2.99E-02	3.37E-01	1.61E-02	8.43E-03	4.04E-04
7.50%	6.32E-01	6.32E-01	1.44E-01	5.33E-01	8.68E-02	1.33E-02	2.17E-03
10.00%	8.28E-01	8.28E-01	4.50E-01	7.30E-01	2.97E-01	1.82E-02	7.42E-03
12.50%	1.02E+00	1.02E+00	1.10E+00	9.26E-01	7.77E-01	2.31E-02	1.94E-02
15.00%	1.22E+00	1.22E+00	2.31E+00	1.12E+00	1.71E+00	2.80E-02	4.27E-02
55.00%	1.22E+00	1.22E+00	2.31E+00	1.22E+00	2.31E+00	4.88E-01	9.26E-01
55.00%	1.18E+00	1.18E+00	2.02E+00	1.20E+00	2.17E+00	0.00E+00	0.00E+00
80.00%	1.18E+00	1.18E+00	2.02E+00	1.18E+00	2.02E+00	2.95E-01	5.04E-01
82.50%	1.04E+00	1.04E+00	1.17E+00	1.11E+00	1.59E+00	2.77E-02	3.98E-02
85.00%	8.96E-01	8.96E-01	6.28E-01	9.67E-01	8.99E-01	2.42E-02	2.25E-02
87.50%	7.54E-01	7.54E-01	3.03E-01	8.25E-01	4.66E-01	2.06E-02	1.16E-02
90.00%	6.11E-01	6.11E-01	1.25E-01	6.83E-01	2.14E-01	1.71E-02	5.36E-03
92.50%	4.69E-01	4.69E-01	4.11E-02	5.40E-01	8.33E-02	1.35E-02	2.08E-03
95.00%	3.27E-01	3.27E-01	8.97E-03	3.98E-01	2.50E-02	9.96E-03	6.26E-04
97.50%	1.85E-01	1.85E-01	8.10E-04	2.56E-01	4.89E-03	6.40E-03	1.22E-04
100.00%	4.30E-02	4.30E-02	1.71E-06	1.14E-01	4.06E-04	2.85E-03	1.02E-05
Average						1.000	1.585

b.) The dose response function method multiplies the SAS2H generated assembly source at average burnup by the corresponding dose response (mrem/hr/particle). The MCNP dose response runs therefore must include a tally multiplier (TM) to adjust for the complete basket source. The tally multiplier is based on the number of fuel assemblies in the basket, and for neutron cases the subcritical neutron multiplication adjustment and the correction for source at average burnup to integrated source (e.g., PWR neutron source TM=69.5=37*1.127*1.667).

c.) The SKYSHINE-III manual includes all relevant information on transmission and reflection information requested. Discussions on Monte Carlo sampling are included within the SKYSHINE-III manual. A SKYSHINE-III manual may be obtained as part of RSICC Code Package CCC-289.

d.) Per a.) the source equation was incorrectly displayed in the SAR. A consistent use of "b" as the exponent should have been employed.

e.) The number of fuel regions is not relevant to the shielding evaluations as source sampling (and source magnitude) at any specific elevation is controlled by the probability profile (in this case burnup profile) entered into the analysis. Discussions on the burnup profile, in particular for low burnup and blanket fuel assemblies, are included in RAI 5-1, 5-7, and 5-8.

f.) NAC agrees that radiation scatter from hard surfaces (such as the cask pad or surrounding surfaces) may play a significant role in the total dose rate around the ISFSI and the code only terminates tracks of particles directly intersecting adjacent casks. A typical cask array of 11.5 foot diameter casks does not provide a significant open area for radiation scatter from the radial surface of the "shadowed" cask to influence the off-site dose primarily dominated by the "front" row casks. Note that only particles originating from the cask radial surface have any potential to intersect casks within the skyshine array. To demonstrate that the assumption of terminating tracks does not have a significant effect on site boundary dose rates, MCNP evaluations were performed on a 2x10 cask array set with the evaluated source limited to the radial (cylindrical) surfaces of the back row of 10 casks. Dose rates are plotted in the following figure along the axis of the side facing the back row and front row of the array assuming the front row of casks are at a nominal importance (1) and at an importance of 0 (i.e., terminating the particle track). As shown in the figure, there is no significant effect of the assumption to terminate cask scattered particles.

<u>Proposed Resolution</u>
Category 2

a.) The SAR is revised to include the technical discussion shown above.
b.) As the manual is copyrighted material, NRC to obtain the relevant code manual and references.
c.) The SAR is revised to correct the equations.
d.) SAR changes are made in RAI 5-1, 5-7, and 5-8 to address profile concerns.
e.) The SAR is revised to augment the discussions involved with particle track termination and to include the MCNP comparison to demonstrate the acceptability of the "terminate particle" assumption.

Draft SAR Text Change

Section 5.4, page 5.4-1 is revised to contain the following content.

"Neutron and gamma source rates are related to burnup by $S \sim aB^b$, where "S" is the source rate for a particular radiation type, "B" is the burnup at a given axial elevation, and ***"b"*** is 1.0 for gamma (photons) and 4.22 for neutrons. ***The "b" factors having been set by curve fitting of SAS2H produced source magnitudes.*** The axially integrated source of an assembly is, therefore, equal to that of the assembly at average burnup for gamma but not neutrons. The fuel neutron and fuel gamma source rate profiles for PWR and BWR fuel are shown in Table 5.4-1 and Table 5.4-2, respectively.

Two scaling quantities are of interest. First, since SAS2H analyses are conducted at the average assembly burnup, a scale factor is required to relate the assembly average source rate to the source rate at the average burnup:

$$r = \frac{\overline{S}}{S(\overline{B})} = \frac{\frac{a}{H}\int B^b dz}{a\overline{B}^b}$$

where H is the height of the fuel region. With the burnup profile normalized to one, this becomes

$$r = \frac{1}{H}\int B^b dz$$

The integral is evaluated numerically using the trapezoid rule, and the resulting scale factors are shown in Table 5.4-1 for PWR fuel and Table 5.4-2 for BWR fuel. The second scaling parameter is the ratio of the peak to average source rate.

$$s = \frac{S(B_{max})}{\overline{S}}$$

This parameter is also shown in Table 5.4-1 (PWR) as 1.127 and Table 5.4-2 (BWR) as 1.585.

The dose response function method multiplies the SAS2H generated assembly source at average burnup by the corresponding dose response (mrem/hr/particle). The MCNP dose response runs therefore must include a tally multiplier (TM) to adjust for the complete basket source. The tally multiplier is based on the number of fuel assemblies in the basket, and for

neutron cases the subcritical neutron multiplication adjustment and the correction for source at average burnup to integrated source (e.g., PWR neutron source TM=69.5=37*1.127*1.667)."

Table 5.4-1 PWR Source Profile Integration

% Core Height	Burnup Profile	Photon Source	Neutron Source	Photon Interval	Neutron Interval	Photon Weight	Neutron Weight
0.00%	0.5470	0.5470	7.84E-02				
2.50%	0.6358	0.6358	1.48E-01	5.91E-01	1.13E-01	1.48E-02	2.83E-03
5.00%	0.7247	0.7247	2.57E-01	6.80E-01	2.02E-01	1.70E-02	5.06E-03
7.50%	0.8135	0.8135	4.19E-01	7.69E-01	3.38E-01	1.92E-02	8.44E-03
10.00%	0.9023	0.9023	6.48E-01	8.58E-01	5.33E-01	2.14E-02	1.33E-02
12.50%	0.9912	0.9912	9.63E-01	9.47E-01	8.06E-01	2.37E-02	2.01E-02
15.00%	1.0800	1.0800	1.38E+00	1.04E+00	1.17E+00	2.59E-02	2.93E-02
85.00%	1.0800	1.0800	1.38E+00	1.08E+00	1.38E+00	7.56E-01	9.69E-01
87.50%	0.9912	0.9912	9.63E-01	1.04E+00	1.17E+00	2.59E-02	2.93E-02
90.00%	0.9023	0.9023	6.48E-01	9.47E-01	8.06E-01	2.37E-02	2.01E-02
92.50%	0.8135	0.8135	4.19E-01	8.58E-01	5.33E-01	2.14E-02	1.33E-02
95.00%	0.7247	0.7247	2.57E-01	7.69E-01	3.38E-01	1.92E-02	8.44E-03
97.50%	0.6358	0.6358	1.48E-01	6.80E-01	2.02E-01	1.70E-02	5.06E-03
100.00%	0.5470	0.5470	7.84E-02	5.91E-01	1.13E-01	1.48E-02	2.83E-03
Average						1.000	1.127

Table 5.4-2 BWR Source Profile Integration

% Core Height	Burnup Profile	Photon Source	Neutron Source	Photon Interval	Neutron Interval	Burnup Weight	Neutron Weight
0.00%	4.30E-02	4.30E-02	1.71E-06				
2.50%	2.39E-01	2.39E-01	2.39E-03	1.41E-01	1.20E-03	3.53E-03	2.99E-05
5.00%	4.35E-01	4.35E-01	2.99E-02	3.37E-01	1.61E-02	8.43E-03	4.04E-04
7.50%	6.32E-01	6.32E-01	1.44E-01	5.33E-01	8.68E-02	1.33E-02	2.17E-03
10.00%	8.28E-01	8.28E-01	4.50E-01	7.30E-01	2.97E-01	1.82E-02	7.42E-03
12.50%	1.02E+00	1.02E+00	1.10E+00	9.26E-01	7.77E-01	2.31E-02	1.94E-02
15.00%	1.22E+00	1.22E+00	2.31E+00	1.12E+00	1.71E+00	2.80E-02	4.27E-02
55.00%	1.22E+00	1.22E+00	2.31E+00	1.22E+00	2.31E+00	4.88E-01	9.26E-01
55.00%	1.18E+00	1.18E+00	2.02E+00	1.20E+00	2.17E+00	0.00E+00	0.00E+00
80.00%	1.18E+00	1.18E+00	2.02E+00	1.18E+00	2.02E+00	2.95E-01	5.04E-01
82.50%	1.04E+00	1.04E+00	1.17E+00	1.11E+00	1.59E+00	2.77E-02	3.98E-02
85.00%	8.96E-01	8.96E-01	6.28E-01	9.67E-01	8.99E-01	2.42E-02	2.25E-02
87.50%	7.54E-01	7.54E-01	3.03E-01	8.25E-01	4.66E-01	2.06E-02	1.16E-02
90.00%	6.11E-01	6.11E-01	1.25E-01	6.83E-01	2.14E-01	1.71E-02	5.36E-03
92.50%	4.69E-01	4.69E-01	4.11E-02	5.40E-01	8.33E-02	1.35E-02	2.08E-03
95.00%	3.27E-01	3.27E-01	8.97E-03	3.98E-01	2.50E-02	9.96E-03	6.26E-04
97.50%	1.85E-01	1.85E-01	8.10E-04	2.56E-01	4.89E-03	6.40E-03	1.22E-04
100.00%	4.30E-02	4.30E-02	1.71E-06	1.14E-01	4.06E-04	2.85E-03	1.02E-05
Average						1.000	1.585

Section 5.1.3, page 5.1-3 is revised to clarify cask "self-shielding".

"… NAC-CASC primary enhancements to SKYSHINE-III allow the input of an angular surface current and the accounting of concrete cask self-shielding ***(i.e., radiation emitted from one-cask intersecting another cask in the array, in particular front/back row interaction in the array)*** ~~***in the array***~~. Both a single cask and a 2×10 array of casks are evaluated. Each cask in the array is assigned the …"

Section 5.5, page 5.5-1 is revised as follows:

"NAC-CASC, a modified version of SKYSHINE-III, uses the MCNP generated cask surface current to estimate site boundary exposures. NAC-CASC allows for self-shielding of casks and permits input of an angular surface current emission spectrum. In the NAC-CASC evaluations, the concrete casks are modeled as "black" body cylinders. Given the concrete cask thickness, radiation emitted from one cask and impacting an adjacent cask will not significantly impact site boundary dose rates. ***To verify the acceptability of this assumption, a radial neutron and gamma source MCNP analysis was performed on a 2x10 cask array with the front row assigned either an importance of 1 (same as back row casks) or assigned an importance of 0 (terminating the particle tracking). Results of this analysis are shown in Figure 5.5-7 for the short array axis (facing the x direction 2 cask side of the array in Figure 5.5-6) and Figure 5.5-8 for the long array axis (facing the y direction 10 cask side of the array in Figure 5.5-6). While significantly affecting the radial dose contribution from the "shielded" back row of casks along the y-axis, the "black body" assumption does not significantly affect total dose rates in this direction as the majority of dose is contributed by the front row of casks (i.e., casks facing the detector). Including the axial contribution in the comparison, which is not affected by the "black body" assumption, would further decrease the relative effect of the black body assumption.*** The energy and angular spectrum of radiation emitted from the cask surface are retained when transitioning from the MCNP to the NAC-CASC model.

Figure 5.5-7 NAC-CASC "Black Body" Assumption Test along Short (X-Axis) Side of Array

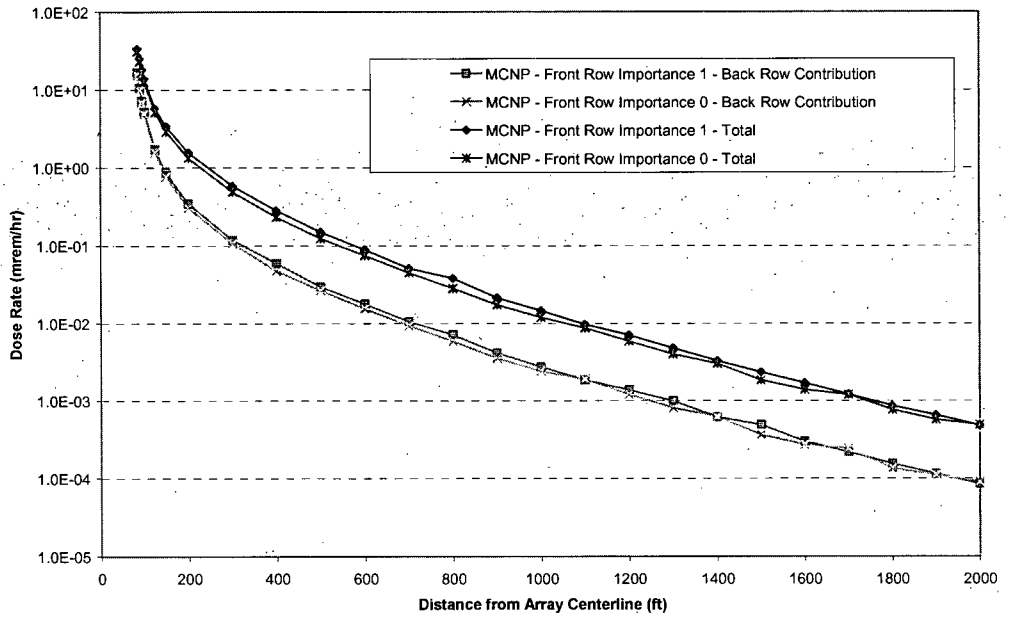
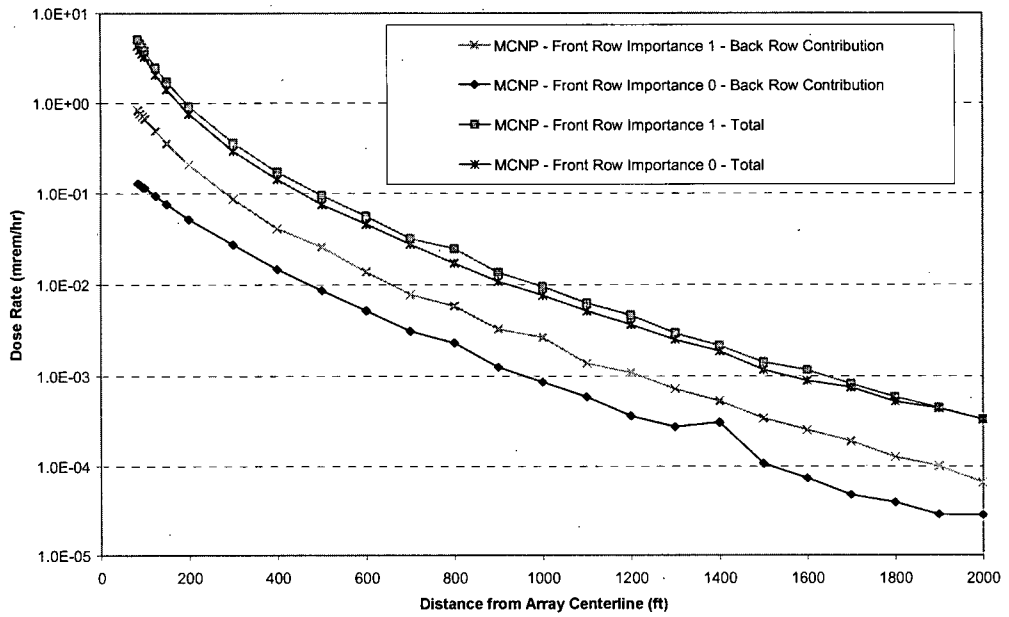


Figure 5.5-8 NAC-CASC "Black Body" Assumption Test along Long (Y-Axis) Side of Array



Section 5.6 Shielding Evaluation

Section 5.8.1 Contents Description

5-10 Draft RAI

Clarify the bounding parameters for the PWR and BWR fuels to be stored in the MAGNASTOR system. Provide information on the enrichments, burnups, and cooling time for those bounding fuel assemblies.

On page 5.8.1-3 and page 5.8.1-4 of the SAR, geometry data is provided for the hybrid fuel assemblies which have the bounding values for the PWR and BWR spent fuel assemblies to be loaded into the MAGNASTOR system. The SAR further, in Figure 5.8.2-1, provides a comparison of the radiation dose rate between the results of the direct method and response method for a hybrid assembly with 3.7wt% enrichment, 40GWD/MTU burnup, and 5 year cooling time. It is not clear, however, if these are the bounding values used in the shielding evaluations.

This information is needed for the staff to determine if the MAGNASTOR system design meets the shielding safety requirements pursuant to 10 CFR 72.104, 72.126, 72.128, 20.1201, and 20.1301.

Summary of Technical Discussion

Bounding fuel parameters are initially discussed in the first paragraph of Section 5.2. This paragraph contains information on the selection of fuel assemblies to evaluate and provides references to the tables containing the key characteristic of each assembly hybrid, i.e., its active fuel mass. Section 5.2 references to Section 5.8.1 for further hybrid fuel assembly information. The paragraph is duplicated below:

> "To generate radiation and thermal source terms, the PWR and BWR fuel assembly types are surveyed and grouped by primary characteristics critical to shielding and source term evaluations. Critical criteria are the basic reactor type in which the fuel assembly operated, fuel mass (MTU), and hardware mass. For each assembly group, a hybrid assembly is generated. The hybrid assembly contains the maximum fuel mass and hardware masses of any assembly within the group. This combination leads to a conservative source term in each TSC. The critical characteristics are listed in Table 5.2.3 1 for PWR assemblies and Table 5.2.3 2 for BWR assemblies. Fuel assembly hardware quantities for nonzirconium-based hardware are included in Section 5.8.1. This hardware may contribute significantly to cask surface dose rates as a result of ^{59}Co activation. Refer to Section 5.8.1 for the geometry aspects and hardware quantities of the evaluated PWR and BWR fuel assembly hybrids."

Section 5.2 also contains information on the enrichments, burnups, and evaluated cooling time for the hybrid assemblies. The last paragraph of this section states:

"Rather than determining a single cool time, assembly average burnup, and initial enrichment combination acceptable for all payloads, source terms are produced in the following range.

- Assembly average burnup from 10,000 MWd/MTU to 60,000 MWd/MTU
- Assembly average initial enrichment 1.3 wt% ^{235}U to 4.9 wt% ^{235}U
- Cool time from 4 years to 90 years (nonfuel hardware is evaluated at cool times down to two years)"

Minimum cooling time is based on meeting system heat load requirements which varies based on uniform or preferential loading patterns and allowed system heat loads. PWR minimum cool time for the shielding based source term heat load of 37 kW are listed in Section 5.8.3 for uniform heat loads and in Section 5.8.7 for preferential heat loads. The thermal analysis limited the PWR heat load to 35.5 kW and required the regeneration of minimum cool time tables. The 35.5 kW PWR tables are included in Section 5.8.9. BWR minimum cool times for a system heat load of 35 kW are listed in Section 5.8.4. System dose rates are reported at the 35 kW heat load level. The design basis thermal analysis limited 33 kW BWR cool times are listed in Section 5.8.9.

Section 5.8.1, "Content Description," contains further information on the hybrid fuel assemblies evaluated for maximum system dose rates. This information includes axial extents of the source regions for each fuel assembly class (hybrid) and the maximum (bounding) fuel hardware masses applied to each assembly design. Tables 5.8.1-1 and 5.8.1-2 for PWR assemblies, and Tables 5.8.1-4 and 5.8.1-5 contain the hybrid fuel assembly characteristics evaluated in the source term and shielding evaluations.

Dose rates are developed for all fuel assembly hybrids as discussed in Section 5.6.1.1. While specific hybrids produce maximum dose rates, all fuels are evaluated at limiting heat loads, therefore a number of fuel types produce similar maximum dose rates. Table 5.1.1-3 contains the list of assemblies producing maximum dose rates at the various cask surfaces.

Section 5.8.2 discussions on a 3.7wt% enrichment, 40GWD/MTU burnup, and 5 year cooling time assembly are related solely to the response function validation. It is not indicated to be the bounding configuration. Additional discussions on the response function method are included as part of the draft RAI 5-11 response.

<u>Proposed Resolution</u>
Category 2

Headings for Figure 5.8.1-1, -2, -4, and -5 are revised to clarify that the tables contain the bounding hybrid characteristic sets.

<u>Draft SAR Text Change</u>

Table titles are modified as follows:

Table 5.8.1 1 PWR ***Hybrid*** Fuel Assembly Geometry Data

Table 5.8.1 2 PWR ***Hybrid*** Fuel Assembly Nonzirconium Alloy-Based Hardware Mass

Table 5.8.1 4 BWR ***Hybrid*** Fuel Assembly Geometry Data

Table 5.8.1 5 BWR ***Hybrid*** Fuel Assembly Nonzirconium Alloy-Based Hardware Quantities

5-11 <u>Draft RAI</u>

Provide and update the SAR to address the following information regarding the validity of the response function method:

(a) Provide detailed information on how the values of the parameters in the response function method are determined for the transfer cask and the concrete storage cask respectively. Add a table(s) to the SAR that lists the response functions for the applicable energy groups and cask configurations applied in the shielding calculations.

(b) The theoretical basis for this method with derivation or reference(s) that can prove the validity of this method.

(c) Explain why the hybrid fuel assembly with an enrichment of 3.7 wt% and 40 GWD/MTU burnup is chosen as case for comparison of the two methods, i.e., response function method and direct method.

(d) Provide a technical basis that proves that the response function method provides better prediction of the dose rate in comparison with the direct method.

(e) Provide the theoretical derivation in the SAR that can prove the accuracy and correctness of this method.

(f) Specify the uncertainties of the methodology and results.

On page 5.8.2-2 of the SAR, the applicant compared the results of the response function method with that of a direct method for an artificial fuel assembly with an enrichment of 3.7 wt% and 40 GWD/MTU burnup. The results show a good agreement between these two methods. The applicant further states: "As a general rule, the response function method provides a better prediction of the dose rate than the direct method due to the much larger number of particles sampled for a given source." It is not clear to the staff what is the direct method the applicant refers to, why this particular representative assembly is used for comparison of these two methods, and how the method is derived and how it is validated. The staff's understanding is that one data point cannot establish the basis for assessing the validity of a method.

This information is needed for the staff to determine if the MAGNASTOR system design meets the shielding safety requirements pursuant to 10 CFR 72.104, 72.126, 72.128, 20.1201, and 20.1301.

Summary of Technical Discussion

NAC presented the theoretical basis of the response function in Section 5.8.2. Maximum dose rates are calculated by following the steps below:

- Calculate the gamma and neutron source spectrum for each fuel type at the Section 5.2 listed burnup, enrichment, and cool time matrix – resulting in gamma/sec or neutron/sec sources (gamma/sec-kg for fuel hardware).
- Based on maximum allowed heat load, search the burnup/initial enrichment matrix for each assembly hybrid to determine minimum cool time for each combination
- For each fuel type, source region, and energy group, run an MCNP Monte Carlo calculation for every detector of interest – resulting in a dose rate per unit source for each detector surface (mrem/hr/source particle/sec).
- Multiply the source in each energy group by the respective response function and total the resulting dose rate.
- Search the resulting dose rates for maximum detector dose rates and highest average dose rates.

The multiplication of response by source spectrum is listed in detail within Section 5.8.2:

"In general, the response method for dose rates is based on the decomposition of the respective quantity into a weighted sum over energy. A dose rate response function, $R_{tpg}(\vec{r})$, gives the response at a point $\vec{r}$ to source particles arising from energy group g from a fuel assembly placed in basket position p. In practice, the spatial parameter, $\vec{r}$, is represented as discrete subsurface detectors on the cask surface. In addition, responses for detector average and maximum values may also be represented using this notation. In the case of a dose rate response, the response $R_{tpg}(\vec{r})$ is a scalar quantity.

For a given TSC loading, the total response to radiation of type t with source spectrum f_{tp} is given by:

$$C_t(\vec{r}) = \sum_p \sum_{g'} R_{tpg'}(\vec{r}) f_{tpg'} w_{tp}$$

where:

$C_t(\vec{r})$ is the dose rate response to radiation of type t at location $\vec{r}$.
$R_{tpg'}(\vec{r})$ is the response to radiation of type t with energy g' emanating from basket position p at location $\vec{r}$.
$f_{tpg'}$ is the source strength for radiation of type t in group g' emanating from basket position p.

> w_{tp} is a weight factor applied to radiation of type t in basket position p and is used to scale hardware source spectra that are provided on a per unit mass basis by the effective mass of activated material present in the source region.
>
> The source type t refers to fuel gamma (Fg), fuel neutron (Fn), fuel n-gamma (Ng), fuel hardware (Hw), upper plenum (Up), upper fitting (Uf), lower plenum (Lp), or lower fitting (Lf) source regions."

As this approach simply represents the summation of dose across energy groups, no theoretical basis beyond the listed summation function is involved. The summation does not involve any further theoretical derivations, does not add any uncertainties, and therefore, does not involve any further discussions on accuracy or correctness. The basic principle is identical to that of any Monte Carlo shielding code in that energy groups are sampled, the resulting dose rate is scaled to a tally multiplier (source term magnitude in the energy groups), and the results summed.

For the storage and transfer PWR and BWR cases, approximately 4000 shielding runs were made (after obtaining a converged weight window for each set of runs). As each case contains multiple detectors (e.g., the radial storage cask has 69 detector and subdetector surfaces defined), listing all response functions within the SAR is not feasible and would not provide any useful information for SAR adequacy review.

The response function provides increased accuracy (i.e., a reduced uncertainty band) based on the larger number of particles sampled. Per the final sentence of Section 5.8.2:

> "As a general rule, the response function method provides a better prediction of the dose rate than the direct results due to the much larger number of particles sampled for a given source."

For Monte Carlo evaluations that are converging based on a normal distribution of particles, the uncertainty of the result corresponds to the square root of the number of particles sampled (assuming that sampling is uniform across all energy groups and the groups contribute equally to the result). The response function allows a much larger number of particles to be sampled in the energy groups responsible for the majority of cask dose as energy lines that do not contribute to cask dose rates can be omitted. Just as importantly, weight windows in each response run are optimized to each source energy group. An increased number of samples, with improved weight windows, results in reduced uncertainty.

The 3.7 wt %, 40 GWd/MTU case represents a "typical" PWR assembly that results in a heat load around 1 kW, in-line with the design basis assembly for the system. The sole purpose of this case is to provide a sample comparison of response to full spectrum "direct" cases and to demonstrate that eliminating high energy / low magnitude lines and low energy / high magnitude lines (that do not penetrate the cask shield) has no significant effect on system results. As

discussed in the previous paragraphs, a sample case is not required to demonstrate the acceptability of the response function method.

Proposed Resolution
Category 2

Section 5.8.2 is augmented to describe the direct case as one containing the full source spectrum produced by the ORIGEN-S code. The section is also revised to include sample neutron and gamma radial response function information for the concrete cask case displayed in Figure 5.8.2-1. The tables clarify that lower energy particles (gammas less than 0.6 MeV and neutrons less than 1.1 MeV) at high source magnitude do not penetrate the cask shield and are therefore inconsequential to the results while similarly high energy lines (above 4 MeV gamma, 11.25 MeV neutron) do not have the source magnitude to be relevant.

Draft SAR Text Change

Revise last paragraph of Section 5.8.2, page 5.8.2-2 to the following:

A comparison of the results of the direct calculation ***(i.e., a calculation based on use of the complete gamma, neutron, or hardware gamma source spectrum in an MCNP run) and dose response method (summation of dose calculation at each energy group)*** is documented to validate the response method, including the reduction in energy lines evaluated. Direct calculation and dose response method results are compared for the radial surface of ……"

Add paragraph and tables as follows:

Sample response functions used in the generation of Figure 5.8.2-1 are included in Table 5.8.2-2 through Table 5.8.2-4. These figures demonstrate the implementation of the dose summation function while simultaneously justifying the reduction in the number of energy lines by example. Energy lines used in the dose assessment are shown in italics and represent 99+% of the total dose. Energy lines with no (0) source magnitude are not included in the tables.

Table 5.8.2-2 Sample Gamma Response Calculation for Concrete Cask Radial Surface – Fuel Centerline (3.7 wt %, 40 GWd/MTU, 5 Year Cooled ng17a Hybrid)

Energy Group	E-Lower (MeV)	E-Upper (MeV)	Response (mrem/hr/g/s)	Source (g/s)	Dose Rate (mrem/hr)
2	1.000E+01	1.200E+01	2.1861E-10	6.9797E+03	1.5259E-06
3	8.000E+00	1.000E+01	1.7643E-10	1.3500E+05	2.3818E-05
4	6.500E+00	8.000E+00	1.3116E-10	6.3583E+05	8.3398E-05
5	5.000E+00	6.500E+00	9.0815E-11	3.2414E+06	2.9437E-04
6	4.000E+00	5.000E+00	5.0103E-11	8.0770E+06	4.0468E-04
7	*3.00E+00*	*4.00E+00*	*2.4050E-11*	*1.0271E+10*	*2.4702E-01*
8	*2.50E+00*	*3.00E+00*	*1.0113E-11*	*8.2537E+10*	*8.3468E-01*
9	*2.00E+00*	*2.50E+00*	*4.4855E-12*	*2.6372E+12*	*1.1829E+01*
10	*1.66E+00*	*2.00E+00*	*1.6408E-12*	*1.1071E+12*	*1.8165E+00*
11	*1.44E+00*	*1.66E+00*	*6.6408E-13*	*4.7865E+12*	*3.1786E+00*
12	*1.22E+00*	*1.44E+00*	*2.6290E-13*	*5.3865E+13*	*1.4161E+01*
13	*1.00E+00*	*1.22E+00*	*7.7024E-14*	*4.2944E+13*	*3.3077E+00*
14	*8.00E-01*	*1.00E+00*	*1.9021E-14*	*3.0365E+14*	*5.7756E+00*
15	*6.00E-01*	*8.00E-01*	*3.1727E-15*	*2.3209E+15*	*7.3634E+00*
16	4.000E-01	6.000E-01	1.8009E-16	7.1107E+14	1.2806E-01
17	3.000E-01	4.000E-01	7.4976E-18	6.6212E+13	4.9643E-04
18	2.000E-01	3.000E-01	8.0028E-19	9.4005E+13	7.5231E-05
19	1.000E-01	2.000E-01	0.0000E+00	3.3053E+14	0.0000E+00
20	5.000E-02	1.000E-01	0.0000E+00	4.1028E+14	0.0000E+00
21	2.000E-02	5.000E-02	0.0000E+00	9.2930E+14	0.0000E+00
22	1.000E-02	2.000E-02	0.0000E+00	6.6321E+14	0.0000E+00
Total (Evaluated Energy Lines)					48.6

Table 5.8.2-3 Sample Neutron Response Calculation for Concrete Cask Radial Surface – Fuel Centerline (3.7 wt %, 40 GWd/MTU, 5 Year Cooled ng17a Hybrid)

Energy Group	E-Lower (MeV)	E-Upper (MeV)	Response (mrem/hr/n/s)	Source (n/s)	Dose (mrem/hr)
2	1.250E+01	1.360E+01	2.0909E-08	1.5460E+04	3.2325E-04
3	1.125E+01	1.250E+01	1.6306E-08	6.4440E+04	1.0508E-03
4	*1.000E+01*	*1.125E+01*	*1.6569E-08*	*2.1410E+05*	*3.5475E-03*
5	*8.250E+00*	*1.000E+01*	*1.2611E-08*	*6.7150E+05*	*8.4685E-03*
6	*7.000E+00*	*8.250E+00*	*1.3746E-08*	*1.8030E+06*	*2.4783E-02*
7	*6.070E+00*	*7.000E+00*	*1.5436E-08*	*3.1120E+06*	*4.8037E-02*
8	*4.720E+00*	*6.070E+00*	*8.5121E-09*	*1.0410E+07*	*8.8611E-02*
9	*3.680E+00*	*4.720E+00*	*3.9797E-09*	*1.7700E+07*	*7.0441E-02*
10	*2.870E+00*	*3.680E+00*	*4.7130E-09*	*2.4000E+07*	*1.1311E-01*
11	*1.740E+00*	*2.870E+00*	*2.9334E-09*	*5.7070E+07*	*1.6741E-01*
12	*6.400E-01*	*1.740E+00*	*7.9695E-10*	*8.8720E+07*	*7.0706E-02*
13	*3.900E-01*	*6.400E-01*	*7.0970E-10*	*2.3080E+07*	*1.6380E-02*
14	*1.100E-01*	*3.900E-01*	*4.7269E-10*	*8.0080E+06*	*3.7853E-03*
15	6.740E-02	1.100E-01	3.4417E-10	2.4200E+02	8.3288E-08
				Total	0.62

Table 5.8.2-4 Sample Hardware Gamma (Upper End-Fitting) Response Calculation for Concrete Cask Radial Surface – Upper End-Fitting Elevation (3.7 wt%, 40 GWd/MTU, 5 Year Cooled ng17a Hybrid)

Energy Group	E-Lower (MeV)	E-Upper (MeV)	Response (mrem/hr/g/s)	Source (g/s)	Dose (mrem/hr)
7	3.000E+00	4.000E+00	2.3514E-10	8.6062E-16	2.0236E-25
8	2.500E+00	3.000E+00	9.9304E-11	2.8344E+04	2.8146E-06
9	2.000E+00	2.500E+00	4.3075E-11	1.8279E+07	7.8737E-04
10	1.660E+00	2.000E+00	1.6115E-11	2.2544E+02	3.6329E-09
11	1.440E+00	1.660E+00	6.7177E-12	4.8588E+00	3.2640E-11
12	*1.22E+00*	*1.44E+00*	*2.6518E-12*	*1.73161E+12*	*4.5919E+00*
13	*1.00E+00*	*1.22E+00*	*9.3485E-13*	*1.82523E+12*	*1.7063E+00*
14	8.000E-01	1.000E+00	2.5075E-13	2.5646E+10	6.4306E-03
15	6.000E-01	8.000E-01	4.5800E-14	3.2226E+06	1.4759E-07
16	4.000E-01	6.000E-01	5.2593E-15	9.2939E+06	4.8879E-08
17	3.000E-01	4.000E-01	1.4491E-16	1.4682E+08	2.1276E-08
18	2.000E-01	3.000E-01	0.0000E+00	1.1190E+08	0.0000E+00
19	1.000E-01	2.000E-01	0.0000E+00	2.2536E+09	0.0000E+00
20	5.000E-02	1.000E-01	0.0000E+00	9.3415E+09	0.0000E+00
21	2.000E-02	5.000E-02	0.0000E+00	2.6718E+10	0.0000E+00
22	1.000E-02	2.000E-02	0.0000E+00	3.1721E+10	0.0000E+00
				Total	6.3

5-12 Draft RAI

Clarify and update the SAR to address the following information regarding the dose rates provided for the transfer cask:

(a) Clarify if the data provided on page 5.8.3-3 of the SAR are for the bounding case.

(b) Provide shielding evaluation calculations for transfer cask, concrete cask, and site boundary including calculation notes, input files, and output files for the bounding case(s) for both PWR and BWR DCSS systems that can demonstrate the selected cases can indeed envelope all of the proposed payloads.

On page 5.8.3-3 of the SAR, the applicant provides dose rate data for transfer cask surface, top, and bottom. It is not clear, however, if these data are the bounding dose rates of the transfer cask. This information is needed for the staff to determine if the MAGNASTOR system design meets the shielding safety requirements pursuant to 10 CFR 72.104, 72.126, 72.128, 20.1201, and 20.1301.

Summary of Technical Discussion

a.) Dose rates on page 5.8.3-3, Section 5.8.3.3 represents the bounding values for the PWR system as Section 5.8.3 contains information for the "37-Assembly PWR System." Maximum dose rates for the BWR transfer cask are presented in Section 5.8.4.3 as part of Section 5.8.4, "87-Assembly BWR System". In particular, Section 5.8.4.3 refers to Table 5.8.4-7 for the maximum BWR system transfer dose rates. Maximum transfer cask dose rates are summarized in Section 5.1.1. Section 5.1.1, page 5.1-2 states:

> "The transfer cask maximum calculated dose rates are shown in Table 5.1.3-1. Payload types producing maximum surface dose rates are listed in Table 5.1.3-3."

The payload information in Table 5.1.3-3 states that the bounding top and radial transfer cask dose rates are produced by the BWR contents and the maximum transfer cask bottom dose rate results from PWR contents.

Preferential loading for the PWR system is addressed in Section 5.8.7 with the dose rate summary table (Table 5.8.7-1) demonstrating that preferentially loading the system produces slightly higher transfer cask average dose rates but slightly lower maximum dose rates.

As indicated on page 5.1-1, Section 5.1, dose rates, and therefore Chapter 11 occupational dose rates, are conservative as they represent heat loads higher than those permitted by the thermal evaluations (Section 5.8.9 contains revised cool time tables due to thermal constraints).

Section 5.6.1 last paragraph states:

> "In the response function method, each of the assemblies, and source regions within an assembly, is analyzed with a unit source in each relevant energy group. These sources are analyzed in a finite number of energy groups with a unit source in each group. The scalar product of source term and response function allows for the creation of large arrays of dose rate results, whether they are for a single detector, or the maximum or average over a detector surface. Further detail on the response function approach to generating dose rates is included in Section 5.8.2."

Based on this approach, all assembly types are evaluated at each source term resulting in maximum dose rates being provided for transfer and storage casks. The response function text is augmented as a result of RAI 5-11.

b.) All MAGNASTOR specific source term, shielding, and occupational exposure calculations are provided as a proprietary submittal under separate cover from this Draft RAI response.

Proposed Resolution
Category 3

No further information is required.

Draft SAR Text Change

SAR text changes are not required.

5-13 Draft RAI

Provide shielding evaluations for the proposed preferential loading pattern.

On page 5.8.9-1 of the SAR, the applicant proposed a preferential loading pattern that allows loading of fuel assemblies with heat load greater than 1000 Watts. The staff's understanding is that the shielding analyses of the MAGNASTOR system is based on the assumption that the maximum assembly heat load will not be greater than 1000 Watts. Although the proposed loading pattern may not exceed the total heat load of the system, it may result in higher dose rates for the TSC, the transfer cask, the concrete cask, or the controlled area boundary of the ISFSI. A separate evaluation of this new loading pattern is warranted.

This information is needed for the staff to determine if the MAGNASTOR system design meets the shielding safety requirements pursuant to 10 CFR 72.104, 72.126, 72.128, 20.1201, and 20.1301.

Summary of Technical Discussion

The shielding evaluations for the preferential loading pattern are based on the same models and calculation methods as those discussed in the uniform shielding analysis section. Specifically, Section 5.8.7 includes the dose analysis for a bounding heat load preferential loading pattern. Section 5.8.7.1 states:

> "Based on a three-zone pattern, the source and tally descriptions are modified in the MCNP models to consider the sources in the appropriate basket locations with the proper scaling on the tally cards. For each cask/detector combination, three sets of runs (A, B and C) are needed to characterize the dose rate response."

Section 5.8.7.2 provides dose rates for the preferential pattern, including a comparison to the uniform pattern, to demonstrate that maximum dose rates are obtained for a uniform loading pattern.

Proposed Resolution
Category 2

Section 5.8.7 is revised to clarify that the models and analysis approach are identical to that of the uniform pattern in that all hybrid fuel types are evaluated at each burnup/initial enrichment/cool time combination to determine maximum and average dose rates. As the only difference in the analysis is a three stage analysis, one per region, with a summation of the resulting dose rates, no further information in this section is required.

Note that as a response to draft RAI 5-12 all MAGNASTOR shielding calculations are being provided.

Draft SAR Text Change

Section 5.8.7 page 5.8.7-1 revised text:

"..... Minimum cool time tables for the thermal analysis limited preferential heat load pattern are included in Section 5.8.9.

The method and models for the preferential loading pattern shielding evaluations are identical to those of the uniform loading pattern with the exception of requiring three sets of response functions, one for each zone. Source spectrum varies as a result of changes in burnup, initial enrichment, and minimum cool time and, therefore, requires cask dose responses (dose per unit source in each spectrum energy group) for each of the zones. The dose responses from each ring, accounting for the differences in the number of assemblies per zone, are added to arrive at the dose rate for a fully loaded cask."

Chapter 9.0 Operating Procedures

9-5 Draft RAI

Revise Section 2.1.2 and remove Section 2.2 of the proposed technical specifications for Approved Contents to eliminate the authority to change fuel parameters in Appendix 1-A. Specify and justify which Appendix 1-A fuel parameters should be controlled in the FSAR, versus those that should be specified as an approved content in the CoC.

The staff is unable to approve this proposed change because NRC regulations in 10 CFR 72.244 prohibit a certificate holder from changing information contained in the CoC by any means other than an amendment to the CoC. Case specific alternatives to approved cask contents listed in the CoC may be submitted to the NRC review via the 10 CFR 72.7 exemption process. The staff recognizes that NUREG-1745, "Standard Format and Content for Technical Specifications for 10 CFR Part 72 Cask Certificate of Compliance" indicates that NRC believes this proposed approach and format is an acceptable means to assure the overall safety goals and removes unnecessary detail from the technical specifications. However, this format does not meet the requirement of 10 CFR 72.244. This information is need to demonstrate compliance with 10 CFR 72.236.

Summary of Technical Discussion

NAC identified that the number of this RAI was probably in error and that it may have intended to be 13-5. Including response to this Technical Specification issue is maintained as 9-5 to minimize potential confusion.

NAC has noted that significant effort had been invested with past NRC staff to establish the current Technical Specification and Appendix 1-A fuel characteristics as presented in the MAGNASTOR SAR resubmittal. Past discussion had addressed the most significant assembly characteristics being captured in the Technical Specifications and a second level of fuel characteristics to be included in Appendix 1-A, Table 1-A-1 and Table 1-A-2. Technical Specification control of Approved Contents 13A 2.0 is configured with two sections; Section 2.1.1 highlights parameters defined in Appendix B and Section 2.1.2 highlights parameters defined in Appendix 1-A. Section 2.2 has been included as a quotation from NUREG-1745 defining regulatory control of second level characteristics without implementation of the formal amendment process. This level of control referencing Table 1-A-1 in Technical Specification Appendix B Table 2-3 and referencing Table 1-A-2 in Technical Specification Appendix B Table 2-10 had been the configuration and direction intended to satisfy both 10 CFR 72.244 and NUREG-1745.

It is noted that NAC response to Draft RAI Part I, 13-4, has proposed the inclusion of the BWR partial length rod configuration in Appendix 1-A. It is recognized that different designs for BWR site specific assemblies may have different partial length rod array patterns and that these differences will not introduce significant impact on system criticality. Based on the known

influence that the partial length rod configuration is not a significant characteristic of the fuel relative to system criticality, and the expectation that system licensees may have different array configurations, the proposed control for this specific characteristic is to include it in Appendix 1-A, committing NRC staff review without implementing the formal amendment process. This proposed path is consistent with past discussion with the staff for Technical Specification control of the fuel characteristics as implemented with NUREG-1745.

Proposed Resolution
Category 3

Based on the stated RAI there appears to be a question on the intended NUREG-1745 implementation process when stating the following:

> "The staff is unable to approve this proposed change because NRC regulations in 10 CFR 72.244 prohibit a certificate holder from changing information contained in the CoC by any means other than an amendment to the CoC. Case specific alternatives to approved cask contents listed in the CoC may be submitted to the NRC review via the 10 CFR 72.7 exemption process. The staff recognizes that NUREG-1745, "Standard Format and Content for Technical Specifications for 10 CFR Part 72 Cask Certificate of Compliance" indicates that NRC believes this proposed approach and format is an acceptable means to assure the overall safety goals and removes unnecessary detail from the technical specifications. However, this format does not meet the requirement of 10 CFR 72.244. This information is need to demonstrate compliance with 10 CFR 72.236."

NAC is of the opinion that NRC internal review of NUREG guidance would assure that the guidance would meet Regulation requirements. However, based on the RAI statement it may now be recognized that the configuration developed through past NAC interface with the NRC staff may not have meet the intended configuration of the NUREG and additional change may be needed.

If requested by NRC management, NAC will incorporate the information currently presented in Appendix 1-A into Technical Specification 13B Section 2.0, delete Appendix 1-A and revise Technical Specification 13A deleting reference to Appendix 1-A and Section 2.1.2.

Draft SAR Text Change

The following is a proposed format change for Technical Specification 13B.

Table 2-3 Bounding PWR Fuel Assembly Loading Criteria

				Max. Initial Enrichment (wt% ^{235}U)[2]					Geometry[3]				
Assembly Type	No. of Fuel Rods	No. of Guide Tubes[1]	Max Load (MTU)	Min Soluble Boron 1500 ppm	Min Soluble Boron 1750 ppm	Min Soluble Boron 2000 ppm	Min Soluble Boron 2250 pm	Min Soluble Boron 2500 ppm	Max Pitch (inch)	Min Clad OD (inch)	Min Clad Thick. (inch)	Max Pellet OD (inch)	Max Active Length (inch)
BW15H1	208	17	0.4858	3.70%	4.10%	4.40%	4.70%	5.00%	0.568	0.43	0.0265	0.3686	144.0
BW15H2	208	17	0.4988	3.70%	4.00%	4.30%	4.60%	4.90%	0.568	0.43	0.025	0.3735	144.0
BW15H3	208	17	0.5006	3.70%	4.00%	4.30%	4.60%	4.90%	0.568	0.428	0.023	0.3742	144.0
BW15H4	208	17	0.4690	3.80%	4.20%	4.50%	4.80%	5.00%	0.568	0.414	0.022	0.3622	144.0
BW17H1	264	25	0.4799	3.70%	4.00%	4.30%	4.60%	4.90%	0.502	0.377	0.022	0.3252	144.0
CE14H1	176	5	0.4167	4.50%	4.80%	5.00%	5.00%	5.00%	0.58	0.44	0.026	0.3805	137.0
CE16H1	236	5	0.4463	4.40%	4.80%	5.00%	5.00%	5.00%	0.5063	0.382	0.025	0.325	150.0
WE14H1	179	17	0.4188	4.70%	5.00%	5.00%	5.00%	5.00%	0.556	0.40	0.0162	0.3674	145.2
WE15H1	204	21	0.4720	3.80%	4.20%	4.50%	4.80%	5.00%	0.563	0.422	0.0242	0.3669	144.0
WE15H2	204	21	0.4469	4.00%	4.40%	4.70%	5.00%	5.00%	0.563	0.417	0.0265	0.357	144.0
WE17H1	264	25	0.4740	3.70%	4.10%	4.40%	4.70%	5.00%	0.496	0.372	0.0205	0.3232	144.0
WE17H2	264	25	0.4327	4.00%	4.30%	4.70%	5.00%	5.00%	0.496	0.36	0.0225	0.3088	144.0

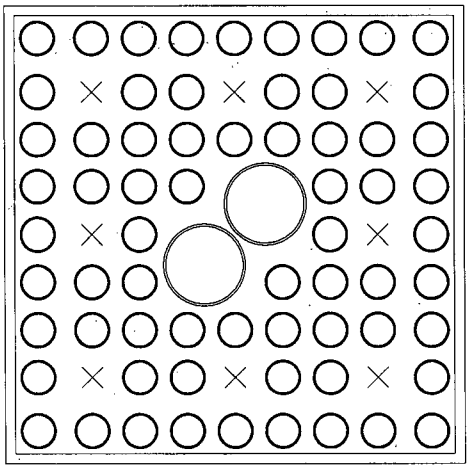
1. Combined number of guide and instrument tubes.
2. Specified soluble boron concentrations are independent of whether an assembly contains a nonfuel insert.
3. Assembly characteristics represent cold, unirradiated, normal configurations.

Table 2-10 BWR Fuel Assembly Loading Criteria

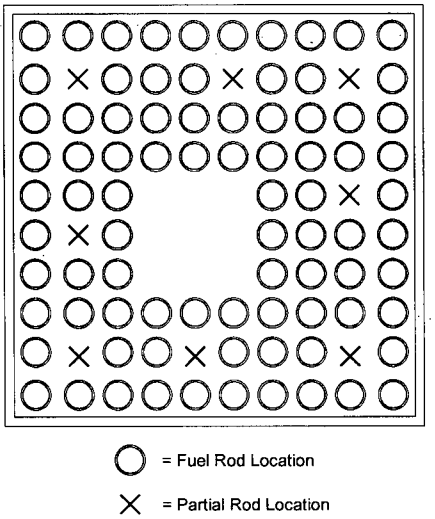
						Geometry [3,4]				
Assembly Type	Number of Fuel Rods	Number of Partial Length Rods [1]	Max Loading (MTU)	87-Assy. Max Enrichment (wt% ^{235}U)	82-Assy Max Enrichment (wt% ^{235}U)	Max Pitch (inch)	Min Clad OD (inch)	Min Clad Thick. (inch)	Max Pellet OD (inch)	Max Active Length (inch)
B7_48A	48	N/A	0.1981	4.00%	4.50%	0.7380	0.5700	0.03600	0.4900	144.0
B7_49A	49	N/A	0.2034	3.80%	4.50%	0.7380	0.5630	0.03200	0.4880	146.0
B7_49B	49	N/A	0.2115	3.80%	4.50%	0.7380	0.5630	0.03200	0.4910	150.0
B8_59A	59	N/A	0.1828	3.90%	4.50%	0.6400	0.4930	0.03400	0.4160	150.0
B8_60A	60	N/A	0.1815	3.80%	4.50%	0.6417	0.4840	0.03150	0.4110	150.0
B8_60B	60	N/A	0.1841	3.80%	4.50%	0.6400	0.4830	0.03000	0.4140	150.0
B8_61B	61	N/A	0.1872	3.80%	4.50%	0.6400	0.4830	0.03000	0.4140	150.0
B8_62A	62	N/A	0.1921	3.80%	4.50%	0.6417	0.4830	0.02900	0.4160	150.0
B8_63A	63	N/A	0.1985	3.80%	4.50%	0.6420	0.4840	0.02725	0.4195	150.0
B8_64A	64	N/A	0.2017	3.80%	4.50%	0.6420	0.4840	0.02725	0.4195	150.0
B8_64B[5]	64	N/A	0.1755	3.60%	4.30%	0.6090	0.4576	0.02900	0.3913	150.0
B9_72A	72	N/A	0.1803	3.80%	4.50%	0.5720	0.4330	0.02600	0.3740	150.0
B9_74A	74[2]	8	0.1873	3.70%	4.30%	0.5720	0.4240	0.02390	0.3760	150.0
B9_76A	76	N/A	0.1914	3.50%	4.20%	0.5720	0.4170	0.02090	0.3750	150.0
B9_79A	79	N/A	0.2000	3.70%	4.40%	0.5720	0.4240	0.02390	0.3760	150.0
B9_80A	80	N/A	0.1821	3.80%	4.50%	0.5720	0.4230	0.02950	0.3565	150.0
B10_91A	91[2]	8	0.1906	3.70%	4.50%	0.5100	0.3957	0.02385	0.3420	150.0
B10_92A	92[2]	14	0.1966	3.80%	4.50%	0.5100	0.4040	0.02600	0.3455	150.0
B10_96A[5]	96[2]	12	0.1787	3.70%	4.30%	0.4880	0.3780	0.02430	0.3224	150.0
B10_100A[5]	100	N/A	0.1861	3.60%	4.40%	0.4880	0.3780	0.02430	0.3224	150.0

1. Location of the partial length rods is illustrated in Figure 2-3.
2. Assemblies may contain partial-length fuel rods.
3. Assembly characteristics represent cold, unirradiated, nominal configurations.
4. Maximum channel thickness allowed is 120 mils (nominal).
5. Composed of four subchannel clusters.

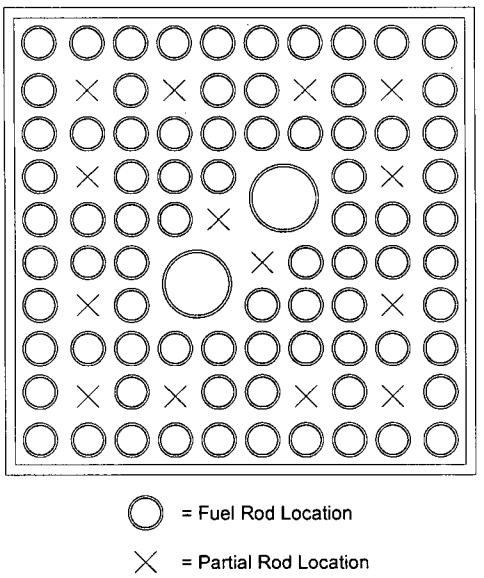
Figure 2-3 BWR Partial Length Fuel Rod Location Sketches



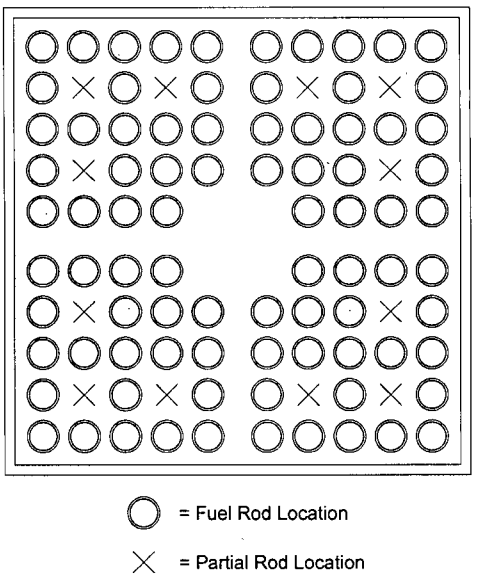
B9_74A 8 Partial Length Rods



B10_91A 8 Partial Length Rods



B10_92A 14 Partial Length Rods



B10_96A 12 Partial Length Rods

Chapter 13.0 Operating Control and Limits

13-1 See Draft RAI Part I

13-2 See Draft RAI Part I

13-3 See Draft RAI Part I

13-4 **Draft RAI**

Add dose rate limits to the proposed technical specifications for the top and side of the transfer cask and the concrete storage cask.

The staff found after reviewing the dose rates and operating procedures that it is necessary to establish dose rate limits for the top and side of transfer cask and concrete storage cask. These dose rates serve several purposes. These dose rates (1) assist with gross mis-load detection and guiding ALARA planning and evaluations; (2) provide confidence that public dose limits will not be exceeded; (3) confirmation of the modeling results at the transfer cask surface gives confidence in the doses calculated at other distances; (4) confirms that the values used as the basis for the radiation protection analyses in the SAR and the site-specific Part 20 ALARA planning was appropriate; and (5) serves to maintain the shielding characteristics of the approved design without unduly restricting the changes that may be made under 10 CFR 72.48.

Summary of Technical Discussion

NAC identified that the RAI cited reasons for requiring dose rate limits to be part of the system Technical Specification did not appear to have a regulatory basis. Also the technical basis is not representative of the actual technology. System shielding calculation are performed for design basis loading and have been demonstrated to conservatively calculate higher combined neutron and gamma dose rates than what are measured in practical application. Therefore, for the proposed limit to be of any real value in performing assessment of loading, actual shielding calculations will be required for each specific loading configuration. Even with the calculation being performed for each canister loading, the ability to identify mis-loading is not a technically acceptable expectation because of the influence of the assemblies in the periphery of the fuel basket array providing shielding to the assemblies loaded in the inner region of the basket.

ALARA planning is performed with design basis calculations presented in Chapter 5 and Chapter 11 and monitored by site RP staff during each loading. It is noted that NAC-UMS systems being loaded currently at operating sites have personnel exposure below 100mrem per cask load cycle. Calculated design basis cumulative dose for loading operations has been estimated in the SAR at significantly higher cumulative dose values.

The only potential control function for adding transfer cask and concrete cask dose rate limits to the Technical Specifications that may have a basis without a current Regulatory requirement would be to create control for the shielding characteristics of the approved design restricting the changes that may be made under 10 CFR 72.48 and implemented by specific site operational

control. Implementing this type of control does not appear to meet the objectives of the industry to provide user flexibility in areas where other systems may be controlling such as 72.104, site boundary dose rates.

Proposed Resolution
Category 3

If requested by NRC management, NAC will incorporate the information currently presented in Chapter 5 for the design basis loading configuration as average dose rate limits for the MAGNASTOR transfer cask and concrete cask into Technical Specification 13A , new Section 3.3.

Draft SAR Text Change

3.3 MAGNASTOR SYSTEM Radiation Protection

3.3.1Transfer Cask Average Surface Dose Rate

LCO 3.3.1 The average surface dose rates of each TRANSFER CASK loading with the canister ready for transfer shall not exceed the following limits unless required ACTION A.1 is met.

a. 1600 mrem/hour (neutron + gamma) on the vertical surface.

APPLICABILITY: During TRANSFER OPERATIONS

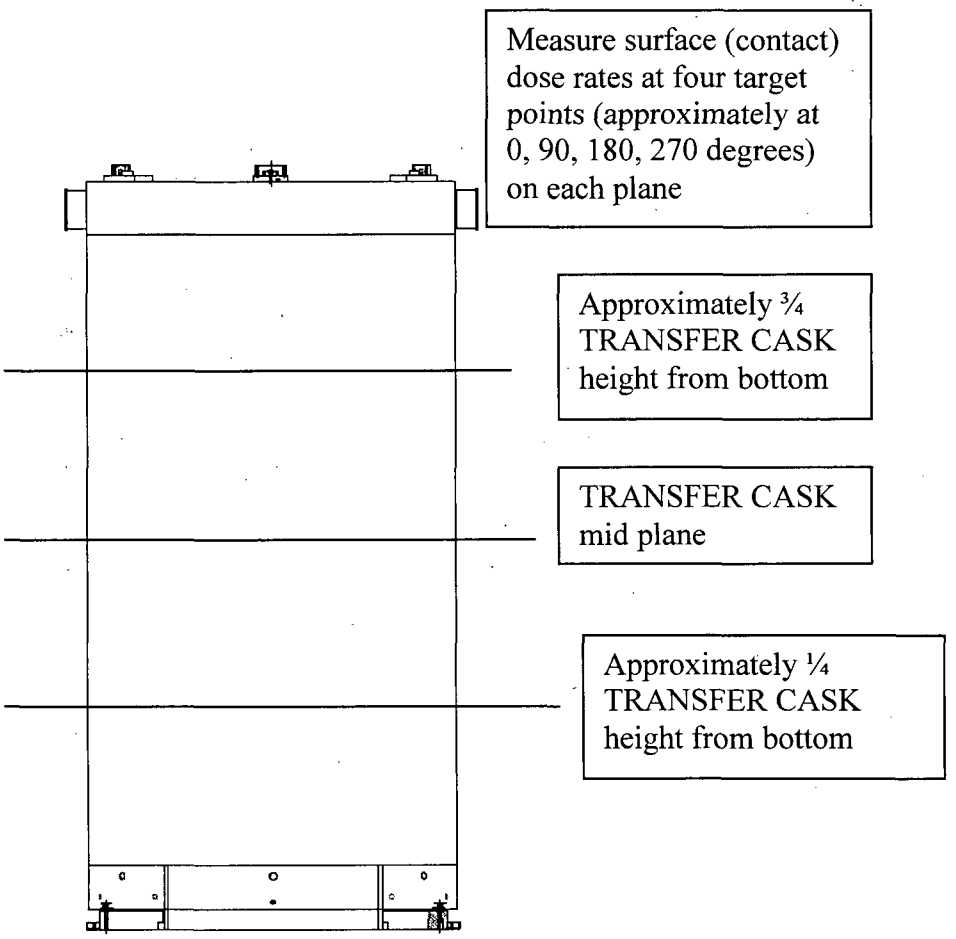
ACTIONS

CONDITION	REQUIRED ACTION	COMPLETION TIME
A. TRANSFER CASK average vertical surface dose rate limits not met	A.1 Administratively verify correct fuel loading	24 hours
B. Required Action and Associated Completion Time not met.	B.1 Perform engineering assessment and establish safe configuration	60 days

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.3.1.1	Verify average surface dose rates of TRANSFER CASK loaded with a dry CANISTER containing dry fuel assemblies are within LCO limits. Dose rates shall be measured at the locations shown in Figure 3-1.	During TRANSFER OPERATIONS

Figure 3-1 TRANSFER CASK Surface Dose Rate Measurement



3.3.2 Concrete Cask Average Surface Dose Rate

LCO 3.3.2 The average surface dose rates of each CONCRETE CASK shall not exceed the following limits unless required ACTIONS A.1 and A.2 are met.

a. 100 mrem/hour (neutron + gamma) on the vertical concrete surfaces; and

b. 450 mrem/hour (neutron + gamma) on the top.

APPLICABILITY: During STORAGE OPERATIONS

ACTIONS

----------NOTE----------

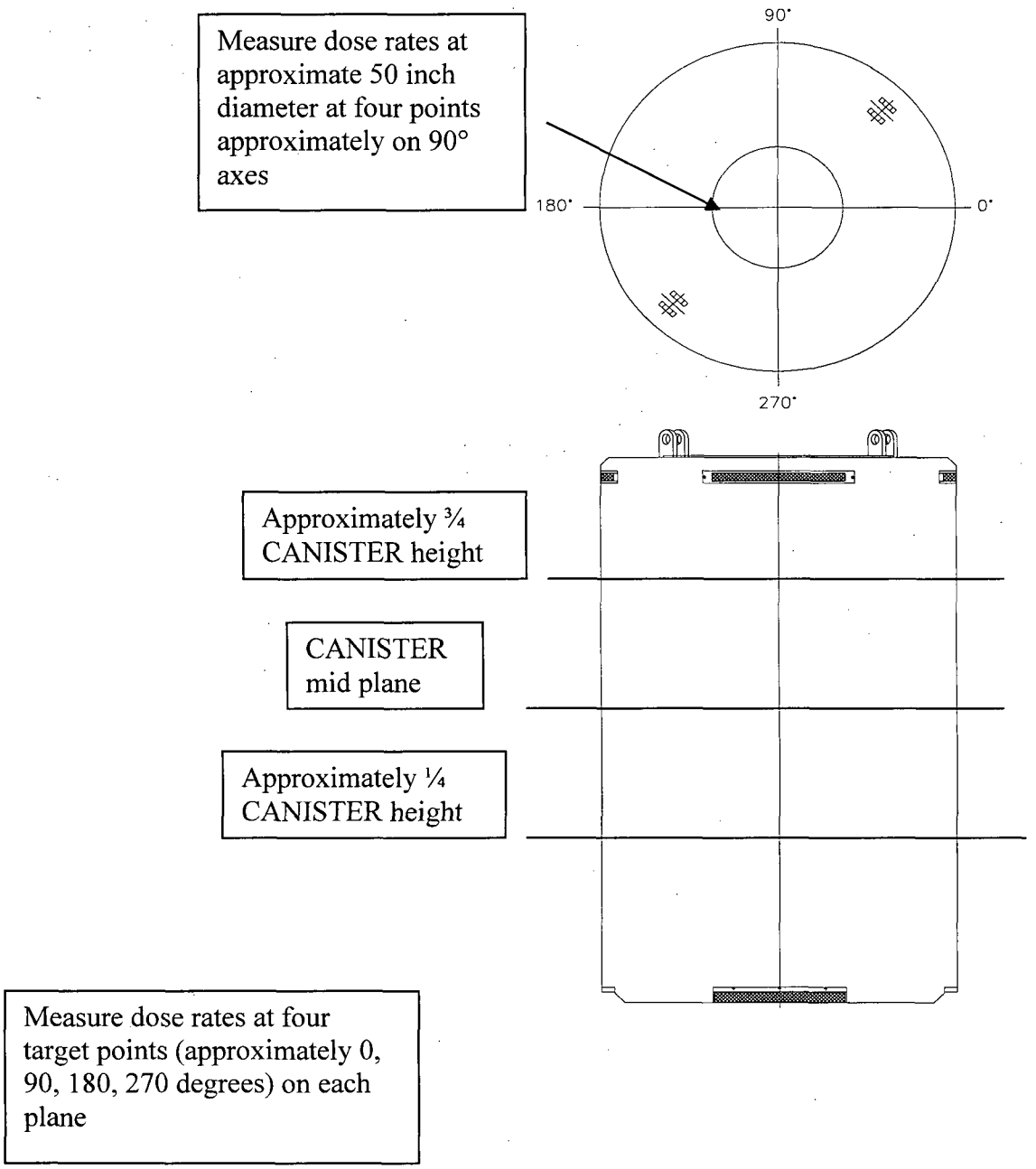
Separate Condition entry is allowed for each MAGNASTOR® SYSTEM.

CONDITION	REQUIRED ACTION	COMPLETION TIME
C. CONCRETE CASK average surface dose rate limits not met	A.1 Administratively verify correct fuel loading AND	24 hours
	A.2 Perform analysis to verify compliance with the ISFSI offsite radiation protection requirements of 10 CFR 20 and 10 CFR 72	7 days
D. Required Action and associated Completion Time not met.	B.1 Perform engineering assessment and establish safe configuration	60 days

SURVEILLANCE REQUIREMENTS

SURVEILLANCE		FREQUENCY
SR 3.2.2.1	Verify average surface dose rates of CONCRETE CASK loaded with a CANISTER containing fuel assemblies are within limits. Dose rates shall be measured at the locations shown in Figure 3-2.	Prior to start of STORAGE OPERATIONS

Figure 3-2 CONCRETE CASK Surface Dose Rate Measurement



13-5 See Draft RAI Part I 13-4

13-6 **Draft RAI**

Add technical specification to the SAR that the licensee(s) shall perform an analysis to confirm that the dose limits of 10 CFR 72.104(a) will be satisfied under the actual cask contents, site conditions, and the ISFSI configuration.

On page 11.4-1 of the SAR, the applicant assures that the MAGNASTOR system meets the requirement of Section 20.1301 of 10 CFR, Part 20 at boundary of the controlled area as evaluated in Chapter 5 of the SAR. Given that the controlled areas evaluated in the radiation shielding chapter are of fairly large sizes, it necessitates a technical specification to define the conditions that an actual MAGNASTOR ISFSI facility must meet.

This information is needed for the staff to perform confirmatory analyses for the shielding safety requirements pursuant to 10 CFR 20.1301, 72.104, and 72.212(b).

Summary of Technical Discussion

NAC identified that the requested change to the Technical Specification is currently included on page 13A-32, Section 5.5.2.

Proposed Resolution
Category 1

Draft SAR Text Change

SAR change is not required.