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September 4, 2009

U.S. Nuclear Regulatory Commission
11555 Rockville Pike
Rockville, MD 20852-2738

Attn: Document Control Desk

Subject: Submittal of NAC International's Responses to U.S. NRC Request for Additional Information for Certificate of Compliance No. 1031 for the NAC International MAGNASTOR® Cask System Amendment Request No. 1 (TAC No. L24330)

Docket No. 72-1031

References:
1. U.S. Nuclear Regulatory Commission (NRC) Certificate of Compliance (CoC) No. 1031 for the NAC International MAGNASTOR Cask System, Amendment No. 0, February 4, 2009
2. MAGNASTOR Cask System Final Safety Analysis Report (FSAR), Revision 0, NAC International, February 2009
3. Submittal of a Request to Amend the U.S. Nuclear Regulatory Commission Certificate of Compliance No. 1031 for the NAC International MAGNASTOR Cask System, NAC International, March 26, 2009
4. Request for Additional Information for Certificate of Compliance No. 1031 for the NAC International MAGNASTOR Cask System Amendment Request No. 1 (TAC No. L24330), NRC, July 6, 2009

NAC International (NAC) herewith submits its response to Reference 4. NAC has prepared the responses to the RAI questions relative to Reference 3, along with the corresponding MAGNASTOR Final Safety Analysis Report (FSAR) changed pages.

Consistent with NAC administrative practice, this proposed FSAR revision is numbered to uniquely identify the applicable changed pages. Revision bars mark the FSAR text changes on the Revision 09B pages, and the included List of Effective Pages identifies the current revision level of all pages in the Reference 2 FSAR.

In order to better facilitate the review process, NAC is providing the Revision 09B changed pages with corresponding backing pages. Consequently, the backing pages are identified as Revision 09A. All changes requested by the responses to the RAI questions are included on Revision 09B changed pages and are marked with revision bars in the margin. In accordance with NAC's administrative practices, upon final acceptance of this application, the Revision 09A and 09B changed pages will be reformatted and incorporated into the next revision of the NAC-MAGNASTOR FSAR.

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This submittal consists of eight copies of this transmittal letter, eight copies of the Reference 4 RAI questions with the NAC responses presented in standard NAC RAI response format, and eight copies of the FSAR Revision 09B changed pages.

The current and recommended FSAR text relative to the acceptance testing of borated aluminum and borated MMC neutron absorber material is based on extensive discussions conducted with the NRC technical staff during the licensing process of the NAC-MAGNASTOR application. Should the Commission find NAC's responses not reflecting the current technical staff's position on the individual questions, NAC hereby would like to request a face-to-face meeting with the technical staff. This interaction will give NAC an opportunity to present and justify its responses and to gain a better understanding of the NRC staff's position on the subject matter.

Approval of this amendment to Reference 1 and the issuance of the draft CoC/Safety Evaluation Report are requested by November 30, 2009, to support fabrication and equipment delivery schedules planned for 2010. Applying the Direct Final Rulemaking process, the estimated/ desired Direct Final Rule effective date is May 31, 2010.

If you have any comments or questions, please contact me on my direct line at 678-328-1274.

Sincerely,

Anthony L. Patko
Director, Licensing
Engineering

Enclosures: NAC Response to US NRC RAI dated July 6, 2009
NAC-MAGNASTOR FSAR Changed Pages (Revision 09B)

NAC INTERNATIONAL

RESPONSE TO THE

UNITED STATES
NUCLEAR REGULATORY COMMISSION

REQUEST FOR ADDITIONAL INFORMATION

JULY 6, 2009

FOR MAGNASTOR® CASK SYSTEM AMENDMENT REQUEST NO. 1 TO DEFINE AND CLARIFY REQUIREMENTS FOR QUALIFICATION AND TESTING OF BORAL NEUTRON ABSORBER MATERIAL

(TAC NO. L24330, DOCKET NO. 72-1031)

SEPTEMBER 4, 2009

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NAC INTERNATIONAL RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

TECHNICAL SPECIFICATIONS (TS)

1. The credit taken for the efficacy of Boral neutron absorbers (75%) should be explicitly stated in the TS. Provide a revised, proposed TS including this information.

   The safety analysis report states the percentage credit given to the efficacy of Boral neutron absorbers for the control of k_{eff}, but that percentage is not stated in the TS.

   This information is needed to determine compliance with 10 CFR 72.124(a).

NAC International Response

U.S. NRC Certificate of Compliance (CoC) No. 1031, Revision 0, Appendix A, Technical Specifications (TS) and Design Features, Section 4.1.1, defines the credit for Boral neutron absorber at 75 percent. The revised wording in Section 10.1.6.4.5 of the original amendment request (Revision 09A) is specific to borated aluminum alloy and, therefore, the wording for Boral was removed.

As the 75% credit for Boral neutron absorber material is currently defined in the Revision 0 TS for CoC No. 1031, the information was not repeated in the amendment request (Revision 09A) Section 10.1.6.4.8.

Therefore, the requested action addressed by RAI 1 is currently documented in the MAGNASTOR Revision 0 CoC and no further action is required.

NAC INTERNATIONAL RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

TECHNICAL SPECIFICATIONS (TS)

2. Provide proposed language for the TS to specify the grade of boron carbide powder (e.g., ASTM C 750 – 03) used in the neutron absorbing materials.

   A nuclear grade of boron carbide powder should be used in applications requiring boron carbide for criticality control, to ensure the quality and the uniformity of properties of the boron carbide powder.

   This information is needed to determine compliance with 10 CFR 72.124(a).

NAC International Response

Historically, NAC has not specified ASTM C 750-03 as an applicable document for the procurement and supply of neutron absorber materials. Material specifications are part of the material supplier's quality assurance program, and contain similar data as that identified in ASTM C 750-03. However, the defined chemical requirements in the material supplier's specification may not be identical to any of the ASTM C-750-03 defined Type 1, 2 or 3 materials. Introducing the requirement for a specific reference to ASTM C 750-03 in the MAGNASTOR TS will result in a series of documentation changes impacting a number of suppliers and their respective specification and documentation processes for materials without any identifiable improvement in material performance or increase in safety.

Neutron absorber material supply is performed under a 10 CFR 72, Part G, quality assurance (QA) program. The application of the QA program provides adequate control of this material to ensure compliance with the requirements of 10 CFR 72.124(a) without invoking specific reference to ASTM C 750-03 and its associated boron carbide definition of Type 1, 2 or 3 materials in the MAGNASTOR TS.

No change to the FSAR is required.

NAC INTERNATIONAL RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

TECHNICAL SPECIFICATIONS (TS)

3. Develop and provide language for the TS, specifying qualifying mechanical test(s) for the neutron absorbing materials.

   The neutron absorbing materials must demonstrate a minimum level of mechanical integrity to ensure proper operation during a hypothetical accident. Mechanical testing is therefore necessary to verify the durability of the neutron absorber materials and cannot be substituted by dimensional measurements or "certified quality-controlled test results," unless such results are explained to the staff's satisfaction.

   Furthermore, the mechanical integrity of laminated neutron absorbing materials is determined not only by the mechanical properties of the aluminum cladding, but also by the bond between the cladding and porous boron carbide/aluminum core. The yield strength of a composite material can only be determined by mechanical testing of the composite, and cannot be determined solely on the yield strength of the cladding.

   Qualitative tests (e.g., ASTM E 290 – 97) demonstrating the mechanical durability of neutron absorbing materials may be acceptable to staff, if the applicant can provide a technical justification, and appropriate acceptance criteria.

   This information is needed to determine compliance with 10 CFR 72.124(a).

NAC International Response

The laminated neutron absorbing material is placed between the fuel tube and the stainless steel retainer plate. This sandwich design provides a continuous and complete support along the full length of the neutron absorber panel. For normal and accident conditions, the laminated neutron absorber, Boral, addressed in the original amendment application (Revision 09A), Section 10.1.6.4.8, is not subjected to bending and the bond between the core and clad is not affected. The bending test (e.g., ASTM E290) for the neutron absorbing material is not representative of neutron absorber panel loading and provides no value relative to material acceptance testing.

NAC International Response to RAI 3 (cont'd)

Therefore, the stated yield strength testing as presented in Section 10.1.6.4.8 is appropriate for the MAGNASTOR design, which provides full support of the Boral panel.

No change to the FSAR is required.

NAC INTERNATIONAL RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

TECHNICAL SPECIFICATIONS (TS)

4. Develop and provide language for the TS to specify the maximum boron or boron carbide content (volume or weight percent) of the neutron absorbing materials to which such materials can be qualified.

   The boron or boron carbide content of the neutron absorbing materials heavily affects the mechanical, thermal, and physical properties of neutron absorbing materials. The applicant should denote the maximum boron or boron carbide content for each individual neutron absorbing material. Conventional fabrication methods of borated aluminum alloys and particle-reinforced metal matrix composites limit the amount of boron and boron carbide that can be incorporated into an aluminum matrix.

   The applicant is encouraged to look at other applications which have been recently approved by the staff to determine what volume or weight percent limits that staff has permitted in such materials.

   This information is needed to determine compliance with 10 CFR 72.124(a).

NAC International Response

It is noted that discussions of maximum boron and boron carbide content had been conducted as a material performance variable during the original MAGNASTOR certification process. Extensive discussions were conducted between the NRC SFST materials review staff and NAC design and licensing staff that resulted in current presentation in FSAR Sections 10.1.6.4.5, 10.1.6.4.6 and 10.1.6.4.7 text, and this text being incorporated into the TS by reference. The above-referenced discussions were addressed in the context of required FSAR content and to be consistent with the certification of materials under development with other applications. The intent was to lead to concurrence on content and approach. Control of the material specification is addressed in Section 10.1.6.4.6, which defines qualification testing, including the requirement for material specification control, and the need to address boron carbide content and any increase in the boron carbide content above that used in previous material qualification.

NAC International Response to RAI 4 (cont'd)

Therefore, the requested action addressed by RAI 4 to specify maximum boron carbide content is currently controlled in the MAGNASTOR CoC, Revision 0 and TS by reference to Section 10.1.6.4.6 as part the material qualification process. An explicit numerical limit is not specified. As material technology and processes advance, identifying maximum boron carbide content in the TS would restrict use of these more advanced materials without the submittal of an amendment application. At the time of the original MAGNASTOR certification effort, which is relatively current with a CoC dated February 4, 2009, issuing the CoC reflected that the current text provided reasonable assurance to the staff that the required performance was adequately controlled and that these material specifications satisfy the requirements of 10 CFR 72.124(a).

No change to the FSAR is required.

NAC INTERNATIONAL RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

TECHNICAL SPECIFICATIONS (TS)

5. Provide proposed language for the TS to specify the maximum total and open porosity of the neutron absorbing materials, and qualifying tests, to measure the total and open porosity.

   Porosity, particularly open porosity, influences the corrosion behavior of the neutron absorbing materials.

   This information is needed to determine compliance with 10 CFR 72.124(e).

NAC International Response

Similar to the response to control of boron and boron carbide content addressed in RAI 4, porosity of the neutron absorbing material is addressed in the MAGNASTOR TS, 4.0 Design Features, Section 4.1.1 through reference to FSAR Section 10.1.6.4.6, which defines qualification testing, and the proposed amended Section 10.1.6.4.6, which limits qualification testing to metal matrix (MMC) and borated aluminum neutron absorber materials. Qualification testing for Boral, where simplification for this specific material testing is based on extensive industry experience and pedigree, is the main focus of this specific amendment application. The pedigree is addressed with the proposed new Section 10.1.6.4.8 (Revision 09A), which adopts established certification basis material testing utilized for currently certified systems using Boral as the neutron absorber material.

Section 10.1.6.4.6 specifically identifies porosity as a material characteristic to be addressed as part of the material qualification process and does not explicitly define a numerical limit. The lack of a specific porosity limit is not expected to be a significant issue for MMC and borated aluminum materials where the actual density is very close to composite theoretical density.

No change to the Revision 09A requested text is required.

NAC INTERNATIONAL RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

SAFETY ANALYSIS REPORT (SAR)

6. In SAR section 10.1.6.4.5, clarify the definition of a "lot" when referring to the number of neutron absorbing panels produced.

   The application does not define a "lot" of neutron absorbing material.

   This information is needed to determine compliance with 10 CFR 72.124(a).

NAC International Response

FSAR Section 10.1.6.2, Terminology, contains definitions for the neutron absorber materials discussion presented in FSAR Section 10.1.6 and all subsections. The term "lot" is included in this material presentation as follows:

> "lot - a quantity of a product or material accumulated under conditions that are considered uniform for sampling purposes"

No change to the FSAR is required.

NAC INTERNATIONAL RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

SAFETY ANALYSIS REPORT (SAR)

7. Justify the use of homogeneous calibration standards, discussed in SAR section 10.1.6.4.5, for calibrating neutron attenuation measurements of neutron absorbing materials. Alternatively, specify that the heterogeneous calibration standards, which are used for neutron attenuation measurements, have been independently calibrated from a widely recognized source.

   The staff is concerned that the use of heterogeneous or secondary calibration standards could result in inaccurate measurements of ^{10}B areal density in neutron absorbing materials.

   This information is needed to determine compliance with 10 CFR 72.124(a).

NAC International Response

NAC agrees to revise the text in Section 10.1.6.4.5, first bullet, which addresses calibrating standards, to the following text, as proposed as an alternative in the NRC stated RAI.

Revised text (Revision 09B):

"Determination of neutron absorber material acceptance shall be performed by neutron attenuation testing. Neutron attenuation testing of the final product or the coupons shall compare the results with those for calibrated standards composed of a homogeneous ^{10}B compound. **The heterogeneous calibration standards, which are used for neutron attenuation measurements, have been independently calibrated from a widely recognized source.** These tests shall include a statistical sample of finished product or test coupons taken from each lot of material to verify the presence, uniform distribution and the minimum areal density of ^{10}B."

NAC INTERNATIONAL RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

SAFETY ANALYSIS REPORT (SAR)

8. Justify and describe the methodology by which the ^{10}B density is determined using radiography. Alternatively, remove radiography as a method used to measure ^{10}B areal density from the application.

   SAR section 10.1.6.4.5 refers to using radiography as a method for determining the ^{10}B areal density. The staff does not believe radiography has ever been used by any applicant to quantify the areal density of ^{10}B in a material.

   This information is needed to determine compliance with 10 CFR 72.124(a).

NAC International Response

Use of neutron radiography validated to neutron attenuation for a specific sheet thickness and B_4C content is a methodology that has been approved by the NRC and used by NAC in the fabrication of the certified NAC-S/T cask currently operational at the Surry Nuclear Power Station. Details of the methodology are not presented in this section of the TS; however, the TS commitment is that this methodology will be validated or calibrated to neutron attenuation testing results and have adequate precision to confirm absorber efficacy. Extensive discussions were conducted between the NRC SFST materials review staff and the NAC design and licensing staff during the MAGNASTOR licensing process that resulted in the current FSAR Section 10.1.6.4.5 text. This text is incorporated into the MAGNASTOR TS by reference.

It is noted that based on past experience, radiography may provide a more comprehensive test of the actual neutron absorber sheet than neutron attenuation testing of sheet sample specimens; however, NAC agrees to remove radiography.

NAC International Response to RAI 8 (cont'd)

Revised text (Revision 09B):

"**An** alternative test method for neutron attenuation may include chemical **analysis, provided** the alternate method has been benchmarked (validated or calibrated) to neutron attenuation testing results and **has** adequate precision to confirm absorber efficacy."

NAC INTERNATIONAL RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

SAFETY ANALYSIS REPORT (SAR)

9. Clarify the second bullet in SAR section 10.1.6.4.5.

The second bullet in SAR section 10.1.6.4.5 appears to allow complete substitution of neutron attenuation acceptance tests by wet chemistry methods for all types of neutron absorbing materials.

For 90% credit of the neutron absorber towards k_{eff}, partial substitution of neutron attenuation acceptance tests by wet chemistry methods is acceptable if the supplier of neutron absorbing materials has conducted a sufficient number of qualifying neutron attenuation tests, and the wet chemistry methods have been benchmarked against neutron attenuation results.

For 75% credit of the neutron absorber towards k_{eff}, neutron attenuation acceptance tests may be completely substituted by wet chemistry methods if the wet chemistry methods have been benchmarked against neutron attenuation results.

This information is needed to determine compliance with 10 CFR 72.124(a).

NAC International Response

As stated in the RAI, the second bullet in Section 10.1.6.4.5 (Revision 09A), permits an alternative test method to neutron attenuation when the alternative test method has been validated or calibrated to neutron attenuation testing results. As originally certified for the MAGNASTOR, this validated methodology is applicable to borated aluminum and MMC neutron absorbers that are limited to 90% credit for the design loading of ^{10}B. The proposed original amendment application (Revision 09A) has included a new Section 10.1.6.4.8 to specifically address Boral as a neutron absorber, where the requirement for wet chemistry methodology to be validated to neutron attenuation test results has been removed for both material qualification and acceptance testing. This proposed material qualification change is based on historic storage system certification practices for Boral , which is being limited to 75% credit for the actual measured ^{10}B content.

NAC International Response (cont'd)

It is noted that the proposed original amendment application (Revision 09A) change to this section of the FSAR is limited to the section title in order to clarify the focus of this section 10.1.6.4.5 to borated aluminum and MMC neutron absorber materials. Extensive discussions were conducted between the NRC SFST materials review staff and the NAC design and licensing staff during the MAGNASTOR application licensing effort that resulted in the current FSAR Section 10.1.6.4.5 text, and this text is incorporated into the TS by reference.

In order to address the RAI clarification of "partial substitution," the second bullet of Section 10.1.6.4.5 is revised as follows:

Revised text (Revision 09B)

"**An** alternative test methods for neutron attenuation may include chemical **analysis, provided** the alternate method has been benchmarked (validated or calibrated) to neutron attenuation testing results and **has** adequate precision to confirm absorber efficacy.

"When alternative test methods are used, a minimum of one test coupon per lot shall be subject to neutron attenuation test acceptance methods."

NAC INTERNATIONAL RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

SAFETY ANALYSIS REPORT (SAR)

10. In SAR section 10.1.6.4.6, remove the word "may" from the sentence: "Typical changes covered by the agreed-upon process controls may include."

    The changes listed should be considered significant changes.

    This information is needed to determine compliance with 10 CFR 72.124(a).

NAC International Response

In the original amendment application (Revision 09A), only the title of Section 10.1.6.4.6 is changed in order to clarify the focus of this section to metal matrix and borated aluminum neutron absorber material. Extensive discussions were conducted between the NRC SFST materials review staff and NAC design and licensing staff during the MAGNASTOR application licensing effort that resulted in the current FSAR Section 10.1.6.4.6 text and its incorporation into the Technical Specifications by reference.

While the request to remove the word "may" from Section 10.1.6.4.6 appears to be a personal preference of the reviewer, NAC agrees to revise the paragraph as follows:

Revised text (Revision 09B):

"Major changes in key manufacturing processes for neutron absorber material shall be controlled by mutually agreed-upon process controls established by the certificate holder/purchaser and the neutron absorber supplier. These process controls will ensure that the neutron absorber delivered will always be consistent with the qualification test material in any and all respects that are important to the neutron absorber's safety characteristics. Changes in the agreed-upon process controls may require requalification of those parts of the qualification that could be affected by the process changes. Typical changes covered by the agreed-upon process **controls include**:"

NAC INTERNATIONAL RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

SAFETY ANALYSIS REPORT (SAR)

11. In SAR section 10.1.6.4.6, clarify the term "minor neutron absorber material processing changes," and distinguish these minor changes from major changes in key manufacturing processes.

    SAR section 10.1.6.4.6 does not clearly distinguish a minor processing change from a major processing change.

    This information is needed to determine compliance with 10 CFR 72.124(a).

NAC International Response

Minor process changes might include the change in a specific roller machine being used for rolling the ingot into the final sheet. Specific process content was purposely left undefined, resulting in the following text: "if such changes do not adversely affect the particle microstructure, i.e., the durability or the uniformity of the boron carbide particle distribution, which is the neutron absorber effectiveness."

In the original amendment application (Revision 09A), only the title of Section 10.1.6.4.6 is changed in order to clarify the focus of this section to metal matrix and borated aluminum neutron absorber material. Extensive discussions were conducted between the NRC SFST materials review staff and NAC design and licensing staff during the MAGNASTOR application licensing effort that resulted in the current FSAR Section 10.1.6.4.6 text and its incorporation into the Technical Specifications by reference. Both "major" and "minor" material process changes were defined in general terms in order to permit flexibility in the process, with assurance that the quality of the neutron absorber sheet was maintained.

NAC International Response to RAI 11 (cont'd)

NAC agrees to revise the FSAR text (Revision 09B) as follows:

- "Minor neutron absorber material processing changes, **i.e. roller machine hardware or final sheet cutting methods, water jet, shear cut , etc. ,** may be determined to be acceptable on the basis of engineering review without additional qualification testing, if such changes do not adversely affect the particle bonding microstructure, i.e., the durability or the uniformity of the boron carbide particle distribution, which is the neutron absorber effectiveness."

NAC INTERNATIONAL RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION

SAFETY ANALYSIS REPORT (SAR)

12. Clarify how physical property measurement, described in the first paragraph of SAR section 10.1.6.4.8, is used to verify the constituents of the neutron absorber.

    Solid materials have a wide range of physical properties. It is unclear what properties are being used to verify the constituents of the neutron absorber material.

    This information is needed to determine compliance with 10 CFR 72.124(a).

NAC International Response

The constituents of the neutron absorber to assure the performance requirements are satisfied consist of two main components: 1) the chemical content of the different materials used to fabricate the sheet; and 2) the physical dimensions of the sheet to be mounted onto the fuel tube wall. The first component is verified by chemical testing of the different materials used in the fabrication of the composite sheet; the cladding material, aluminum powder and boron carbide powder. Traceability of the component material chemical testing to the specific sheet production is made part of the quality record documentation package. The second component of the material acceptance program consists of physical measurement of sheet thickness, width and length. These measurements, in combination with wet chemistry testing, verify that the neutron absorber sheet meets areal density requirements, and the area of poison between each of the adjacent fuel basket cells meets license drawing and FSAR analysis requirements.

In order to provide clarification to the original amendment application (Revision 09A) text, NAC proposes changing "physical property" to "dimensional" in Section 10.1.6.4.8, first paragraph.

NAC International Response to RAI 12 (cont'd)

Revised text (Revision 09B):

"The Boral neutron absorbing material is an aluminum matrix material formed from aluminum and boron-carbide. The mixing of the aluminum and boron-carbide powder forming the neutron absorber material is controlled to assure the required ^{10}B areal density. The constituents of the neutron absorber material shall be verified by chemical testing and by **dimensional** measurement to ensure the quality of the finished plate or sheet. The results of all neutron absorber material tests and inspections, including the results of wet chemistry coupon testing, are documented and become part of the quality records documentation package for the fuel tube and basket assembly."

September 2009

Revision 09B

MAGNASTOR®

(Modular Advanced Generation Nuclear All-purpose STORage)

FINAL SAFETY ANALYSIS REPORT

Docket No. 72-1031

NAC INTERNATIONAL

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Chapter 10

In the Chapter 4 thermal analyses, the neutron absorber is conservatively evaluated as a 0.125-in nominal thickness sheet for the PWR fuel basket and a 0.10-in nominal thickness sheet for the BWR fuel basket. The required minimum thermal conductivities for the MAGNASTOR absorbers are as follows.

Minimum Effective Thermal Conductivity - BTU/(hr-in-°F)

Fuel Basket Type	Radial		Axial	
	100°F	500°F	100°F	500°F
PWR	4.565	4.191	4.870	4.754
BWR	4.687	4.335	5.054	5.017

The neutron absorber thermal acceptance criterion will be based on the nominal sheet thickness. Surface anomalies increase radiation heat transfer and have insignificant influence on thermal conductivity, permitting acceptance of minor surface defects without additional material testing.

Additional thermal conductivity qualification testing of neutron absorber material is not required if certified quality-controlled test results (from an NAC approved supplier) that meet the specified minimum thermal conductivity are available as referenced documentation.

Yield Strength Testing

Yield strength qualification testing of the neutron absorber shall conform to ASTM Test Method B 557/B 557M, E 8 or E 21 [17, 18, 19].

Neutron absorber material yield strength must be equal to or greater than 1.6 ksi at 700°F. Per Table 8.3-16, a yield strength of 1.6 ksi is the material strength of the neutron absorber at 700°F and is applied as a temperature-independent value in the structural evaluations of the absorber. This yield strength assures that the material will maintain its form when subjected to normal, off-normal and accident condition loads.

The neutron absorber yield strength acceptance criterion will be based on the absorber meeting the specified nominal sheet thickness. Control and limitations on the neutron absorber boron content (primary driver to material structural performance) permits acceptance without additional material yield strength acceptance testing.

Additional yield strength qualification testing of neutron absorber material is not required if certified quality-controlled test results (from an NAC approved supplier) that meet the specified minimum yield strength are available as referenced documentation.

10.1.6.4.5 Acceptance Testing of Borated Aluminum Alloy and Borated MMC Neutron Absorber Material by Neutron Attenuation

NOTE

Section 10.1.6.4.5 is incorporated into the MAGNASTOR CoC Technical Specification by reference, Paragraph 4.1.1, and may not be deleted or altered in any way without a CoC amendment approval from the NRC. The text in this section is shown in bold to distinguish it from other sections.

Acceptance testing shall be performed to ensure that neutron absorber material properties for sheets in a given production run are in compliance with the materials requirements for the MAGNASTOR fuel baskets and that the process is operating in a satisfactory manner.

Statistical tests will be run to augment findings relating to isotopic content, impurity content or uniformity of the ^{10}B distribution.

- **Determination of neutron absorber material acceptance shall be performed by neutron attenuation testing. Neutron attenuation testing of the final product or the coupons shall compare the results with those for calibrated standards composed of a homogeneous ^{10}B compound. The heterogeneous calibration standards, which are used for neutron attenuation measurements, have been independently calibrated from a widely recognized source. These tests shall include a statistical sample of finished product or test coupons taken from each lot of material to verify the presence, uniform distribution and the minimum areal density of ^{10}B.**
- **An alternative test method for neutron attenuation may include chemical analysis, provided the alternate method has been benchmarked (validated or calibrated) to neutron attenuation testing results and has adequate precision to confirm absorber efficacy. When alternative test methods are used, a minimum of one test coupon per lot shall be subject to neutron attenuation test acceptance methods.**
- **The ^{10}B areal density is measured using a collimated thermal neutron beam of up to 1.2 cm diameter. A beam size greater than 1.2 cm diameter, but no larger than 1.7 cm diameter, may be used if computations are performed to demonstrate that the calculated k_{eff} of the system is still below the calculated Upper Subcritical Limit (USL) of the system, assuming defect areas the same area as the beam. Following are the required computations for using a neutron beam size greater than 1.2 cm diameter.**

    1. **Defects of the same area as the proposed neutron beam or larger have an areal density significantly below the specified minimum areal density.**

10.1.6.4.6 Qualification Testing of Metal Matrix and Borated Aluminum Neutron Absorber Material

NOTE

Section 10.1.6.4.6 is incorporated into the MAGNASTOR CoC Technical Specification by reference, Paragraph 4.1.1, and may not be deleted or altered in any way without a CoC amendment approval from the NRC. The text in this section is shown in bold to distinguish it from other sections.

Qualification tests for each MAGNASTOR System neutron absorber material and its set of manufacturing processes shall be performed at least once to demonstrate acceptability and durability based on the critical design characteristics, previously defined in this section.

The licensed service life will include a range of environmental conditions associated with short-term transfer operations, normal storage conditions, as well as off-normal and accident storage events. Additional qualification testing is not required for a neutron absorber material previously qualified, i.e., reference can be provided to prior testing with the same, or similar, materials for similar design functions and service conditions.

- **Qualification testing is required for: (1) neutron absorber material specifications not previously qualified; (2) neutron absorber material specifications previously qualified, but manufactured by a new supplier; and (3) neutron absorber material specifications previously qualified, but with changes in key process controls. Key process controls for producing the neutron absorber material used for qualification testing shall be the same as those to be used for commercial production.**
- **Qualification testing shall demonstrate consistency between lots (2 minimum).**
- **Environmental conditions qualification will be verified by direct testing or by validation by data on the same, or similar, material, i.e., the neutron absorber material is shown to not undergo physical changes that would preclude the performance of its design functions. Conditions encountered by the neutron absorber material may include: short-term immersion in water, exposure to chemical, temperature, pressure, and gamma and neutron radiation environments. Suppliers' testing will document the durability of neutron absorber materials that may be used in the MAGNASTOR system by demonstrating that the neutron absorber materials will not incur significant damage due to the pressure, temperature, radiation, or corrosion environments or the short-term water immersion that may occur in the loading and storage of spent fuel.**

- **Thermal conductivity and yield strength qualification testing shall be as previously described in Section 10.1.6.4.4.**
- **The uniformity of the boron carbide distribution in the material shall be verified by neutron attenuation testing of a statistically significant number of measurements of the areal density at locations distributed throughout the test material production run, i.e., at a minimum from the ends and the middle of the run. The sampling plan must be designed to demonstrate 95/95 compliance with the absorber content requirements. Details on acceptable neutron attenuation testing are previously provided in this section for Acceptance Testing. Alternate test methods may be employed provided they are validated (benchmarked) to neutron attenuation tests.**
- **One standard deviation of the neutron attenuation test sampling results shall be less than 10% of the sample mean. This requirement provides additional assurance that a consistent product is achieved by the manufacturing process.**
- **A material qualification report verifying that all design requirements are satisfied shall be prepared.**
- **Key manufacturing process controls in the form of a complete specification for materials and process controls shall be developed for the neutron absorber material by the supplier and approved by NAC to ensure that the product delivered for use is consistent with the qualified material in all respects that are important to the material's design function.**
- **Major changes in key manufacturing processes for neutron absorber material shall be controlled by mutually agreed-upon process controls established by the certificate holder/purchaser and the neutron absorber supplier. These process controls will ensure that the neutron absorber delivered will always be consistent with the qualification test material in any and all respects that are important to the neutron absorber's safety characteristics. Changes in the agreed-upon process controls may require requalification of those parts of the qualification that could be affected by the process changes. Typical changes covered by the agreed-upon process controls include:**
  - **Changes that could adversely affect mechanical properties (e.g., change in thermal conductivity, porosity, material strength, change of matrix alloy, boron carbide content, increase in the B_4C content above that used in previously qualified material, etc.);**
  - **Changes that could affect the uniformity of boron (e.g., change to mixing process for aluminum and boron carbide powders, change in stirring of melt, change in boron precipitate phase, etc.).**

- **Minor neutron absorber material processing changes, i.e., roller machine hardware or final sheet cutting methods, water jet, shear cut, etc., may be determined to be acceptable on the basis of engineering review without additional qualification testing, if such changes do not adversely affect the particle bonding microstructure, i.e., the durability or the uniformity of the boron carbide particle distribution, which is the neutron absorber effectiveness.**
- **Nonconforming material shall be evaluated within the NAC International Quality Assurance Program and shall be assigned one of the following dispositions: "Use-As-Is," "Rework/Repair" or "Reject." Only material that is determined to meet all applicable conditions of the license will be accepted.**

10.1.6.4.7 Additional Material Specifications

NOTE

Section 10.1.6.4.7 is incorporated into the MAGNASTOR CoC Technical Specification by reference, Paragraph 4.1.1, and may not be deleted or altered in any way without a CoC amendment approval from the NRC. The text in this section is shown in bold to distinguish it from other sections.

Boron carbide particles for MMCs shall have an average size in the range 10-40 microns and no more than 10% of the particles shall be over 60 microns. The material shall have negligible interconnected porosity exposed at the surface or edges.

10.1.6.4.8 Boral Neutron Absorber Tests

NOTE

Section 10.1.6.4.8 is incorporated into the MAGNASTOR CoC Technical Specification by reference, Paragraph 4.1.1, and may not be deleted or altered in any way without a CoC amendment approval from the NRC. The text in this section is shown in bold to distinguish it from other sections.

The Boral neutron absorbing material is an aluminum matrix material formed from aluminum and boron-carbide. The mixing of the aluminum and boron-carbide powder forming the neutron absorber material is controlled to assure the required ^{10}B areal density. The constituents of the neutron absorber material shall be verified by chemical testing and by dimensional measurement to ensure the quality of the finished plate or sheet. The results of all neutron absorber material tests and inspections, including the

results of wet chemistry coupon testing, are documented and become part of the quality records documentation package for the fuel tube and basket assembly.

The manufacturing process of Boral consists of several steps. The initial step is the mixing of the aluminum and boron carbide powders that form the core of the finished material. The amount of each powder is a function of the desired ^{10}B areal density. The methods used to control the weight and blend the powders are proprietary processes of the manufacturer.

After manufacturing, test samples from each Boral batch of neutron absorber sheets shall be tested using wet chemistry techniques to verify the presence and minimum weight percent of ^{10}B. The tests shall be performed in accordance with approved written procedures.

The neutron absorber sampling plan is selected to demonstrate a 95/95 statistical confidence level in the neutron absorber sheet material in compliance with the specification. In addition to the specified sampling plan, each sheet of material is visually and dimensionally inspected using at least six measurements on each sheet. The sampling plan is supported by written and approved procedures.

The sampling plan requires that a coupon sample be taken from each of the first 100 sheets of absorber material. Thereafter, coupon samples are taken from 20 randomly selected sheets from each set of 100 sheets. This 1 in 5 sampling plan continues until there is a change in lot or batch of constituent materials of the sheet (i.e., boron carbide powder, aluminum powder, or aluminum extrusion) or a process change. If either of these circumstances occurs, the sampling plan reverts back to a coupon sample being taken from each of the first 100 sheets of absorber material, followed by the 20 randomly selected sheets from each set of 100 sheets. The sheet samples are indelibly marked and recorded for identification. This identification is used to document neutron absorber test results, which become part of the quality record documentation package.

Neutron Absorber Wet Chemistry Testing

Wet chemistry testing of the test coupons obtained from the sampling plan is used to verify the ^{10}B content of the neutron absorber material. Wet chemistry testing is applied because it provides an accurate and practical direct measurement of the boron and B_4C content of metal materials.

An approved facility with chemical analysis capability, which could include the neutron absorber vendor's facility, shall be selected to perform the wet chemistry tests. Personnel