NAC INTERNATIONAL

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December 1, 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
5. 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, NAC International, September 4, 2009
6. 2nd Request for Additional Information (RAI) for Review of Amendment No. 1 to certificate of Compliance (CoC) No. 1031 for the NAC International MAGNASTOR® Cask Storage System and Revised Schedule, NRC, October 26, 2009

NAC International (NAC) herewith submits its response to Reference 6 in accordance with the discussions in the November 23, 2009, teleconference with NRC staff. 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 09C pages, and the included List of Effective Pages identifies the current revision level of all pages in the Reference 2 FSAR.

ED20090119

NMSS01

In order to better facilitate the review process, NAC is providing the Revision 09C changed pages with corresponding backing pages. Consequently, one backing page is identified as Revision 09A. All changes requested by the responses to the RAI questions are included on Revision 09C 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, 09B and 09C changed pages will be reformatted and incorporated into the next revision of the NAC-MAGNASTOR FSAR.

This submittal consists of eight copies of this transmittal letter, eight copies of the Reference 6 RAI questions with the NAC responses presented in standard NAC RAI response format, and eight copies of the FSAR Revision 09C changed pages.

Timely completion of the approval of this amendment to Reference 1 and the issuance of the draft CoC/Safety Evaluation Report is being requested 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 2nd RAI dated October 26, 2009
NAC-MAGNASTOR FSAR Changed Pages (Revision 09C)

NAC INTERNATIONAL

RESPONSE TO THE

UNITED STATES
NUCLEAR REGULATORY COMMISSION

2ND REQUEST FOR ADDITIONAL INFORMATION

OCTOBER 26, 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)

DECEMBER 1, 2009

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NAC INTERNATIONAL RESPONSE
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EDITORIAL 1)

1. The staff proposed in draft Interim Staff Guidance Document 23 (ISG-23) that thermal neutron beams up to 2.54-cm in diameter with a 10-percent tolerance are acceptable for qualification and acceptance testing of boron carbide/aluminum based neutron absorbing materials.[1] In accordance with this guidance, the applicant may choose to increase the size of the neutron beam used for qualification and acceptance testing.

   [1] Draft Interim Staff Guidance Document 23 (ISG-23), "Application of ASTM Standard Practice C1671-07 when performing technical reviews of spent fuel storage and transportation packaging licensing actions," U.S. Nuclear Regulatory Commission, Division of Spent Fuel Storage and Transportation, June 2009.

NAC International Response

Section 10.1.6.4.5 of the MAGNASTOR FSAR is revised to specify neutron attenuation measurements use a collimated thermal neutron beam of up to 2.54 cm in diameter, with a tolerance of 10 percent.

FSAR text associated with beam sizes greater than 1.2 cm, but no larger than 1.7 cm diameter, is removed from the third (now second) bullet of Section 10.1.6.4.5, as a result of allowing the 2.54-cm diameter beam.

NAC INTERNATIONAL RESPONSE
TO
REQUEST FOR ADDITIONAL INFORMATION

RAI 1)

1. Specify a minimum chemical purity, and/or the chemical requirements of the boron carbide powder used in the neutron absorbing materials. Alternatively, specify a nationally recognized standard associated with the boron carbide powder (e.g., ASTM C 750 – 03, Type 1).

   The minimum chemical purity and/or the chemical requirements of the boron carbide powder should be specified to ensure that the overall properties (e.g., corrosion resistance) of the neutron absorbing material are not influenced by contaminants.

   In the past, the staff has accepted the use of ASTM C 750 – 03, Type 1 boron carbide powder. Such a standard specifies the general purity of the powder, minimum boron content, maximum halogen content, and maximum soluble boron.

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

NAC International Response

MAGNASTOR FSAR Section 10.1.6.4.7, "Additional Material Specifications," which is incorporated into the MAGNASTOR CoC Technical Specifications by reference, is revised to include minimum requirements on chemical purity of the boron carbide powder. Chemical composition of the boron carbide powder is specified to meet the requirements of Table 1 of ASTM C 750-03, Type 3.

Type 1 is not applicable, as it applies to "particulate material in nuclear reactor core applications." The particulate in the MAGNASTOR absorber is further processed into the aluminum matrix material and is not used in the reactor core.

Type 2 is not applicable, as it applies to "powder further processed into a fabricated shape for use in a nuclear reactor core or used in non-core applications when the powder directly or indirectly may cause adverse effects on structural components, such as halide stress corrosion of stainless steel." While the MAGNASTOR absorber is a fabricated shape, it is not used in a nuclear

NAC International Response to RAI 1) (cont'd)

reactor and no halide corrosion occurs, as the boron carbide power is trapped within the aluminum matrix and/or, in the case of laminated absorbers, is covered by an aluminum sheet.

Type 3 is, therefore, applied to the MAGNASTOR neutron absorber boron carbide powder. Additional chemical requirements, applicable to a particular absorber material, may be placed on the boron carbide powder as a result of the "key manufacturing process controls" invoked by the eighth bullet in Section 10.1.6.4.6. Additional requirements may include, but are not limited to, upper limits on fluorine and chlorine content.

NAC INTERNATIONAL RESPONSE
TO
REQUEST FOR ADDITIONAL INFORMATION

RAI 2)

2. Clarify how heterogeneous calibration standards for neutron attenuation measurements of neutron absorbing materials are calibrated in Section 10.1.6.4.5 of the application.

   The staff considers the following acceptable for use: *"Standards will be calibrated, traceable to nationally recognized standards, or by attenuation of a monoenergetic neutron beam correlated to the known cross-section of boron 10 at that energy."*

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

NAC International Response

The calibration standard in the first bullet of Section 10.1.6.4.5 of the MAGNASTOR FSAR is revised as follows:

"Neutron attenuation testing of the final product, or the coupons, shall compare the results with those for calibrated standards, which may be composed of homogeneous or heterogeneous materials. The heterogeneous standard will be calibrated to a recognized standard (e.g., homogeneous material such as ZrB_2 plate material or a NIST-produced standard) or by attenuation of a thermal neutron beam correlated to the known cross-section of ^{10}B at the beam energies."

NAC INTERNATIONAL RESPONSE
TO
REQUEST FOR ADDITIONAL INFORMATION

RAI 3)

3. Specify qualifying mechanical test(s) for the neutron absorbing materials in the Technical Specifications.

   The staff understands that no structural credit is given to the neutron absorbers; however, the neutron absorbing materials should demonstrate a minimum level of mechanical integrity to ensure proper operation during a hypothetical accident. Mechanical testing is, therefore, necessary to verify a minimal level of durability for the neutron absorber materials and cannot be substituted by dimensional measurements or "certified quality-controlled test results," unless an explicit explanation of the test results is provided.

   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. Current wording in Section 10.1.6.4.4 of the FSAR appears to permit the use of aluminum clad neutron absorbing materials which have not undergone *any* mechanical qualifying tests.

   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

BORAL, the laminated neutron absorber referred to in the MAGNASTOR FSAR, has been used in a large number of storage and transport systems licensed by US NRC. The absorber core is given no structural credit in the licensing analysis, as stated in the FSAR and referred to in the second paragraph of this RAI. The laminated absorber is located between a steel retainer and the steel fuel tube and is not subjected to bending loads such as those tests specified by ASTM E 290-97. Standard ASTM testing methods for strength and durability are not applicable to the

NAC International Response to RAI 3) (cont'd)

load conditions of the steel supported and enclosed laminated absorber. No technical specification requirements on the laminated absorber are, therefore, included in the FSAR.

No changes are required to the MAGNASTOR FSAR.

NAC INTERNATIONAL RESPONSE
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RAI 4)

4. Specify the maximum total and open porosity of the neutron absorbing materials in the Technical Specifications. Excluding Boral, if the open porosity of the neutron absorbing material is greater than 0.5%, then qualifying tests should be conducted to ensure that the material will not blister when submerged and subsequently dried.

   Porosity, particularly open porosity, influences the corrosion behavior of the neutron absorbing materials. For unclad neutron absorbing materials, a maximum open porosity of 0.5% generally negates the need for blister testing.

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

NAC International Response

MAGNASTOR FSAR Section 10.1.6.4.7, "Additional Material Specifications," which is incorporated into the MAGNASTOR CoC Technical Specifications by reference, is revised to include the requirement for open porosity be less than, or equal to, 0.5% for borated aluminum and borated metal matrix composites (MMC) absorber unless qualification tests are performed to ensure that blisters are not produced under submerging and subsequent vacuum drying conditions.

**NAC INTERNATIONAL RESPONSE
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RAI 5)

5. Specify in the Technical Specifications 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. 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. By bounding the boron carbide content (typically volume 40%), the staff is able to make general determinations about the validity of the bounding properties of the neutron absorbing material reported in the application (e.g., thermal conductivity, elastic modulus, etc.).

   The applicant is encouraged to look at other licensing actions taken 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

Qualification testing required of the borated aluminum and metal matrix composites (MMC) ensures that the materials will meet system performance requirements—in particular, thermal conductivity and yield strength. These requirements implicitly limit the quantity of boron carbide in the neutron absorber borated aluminum and MMC materials.

No changes are required to the MAGNASTOR FSAR.

NAC INTERNATIONAL RESPONSE
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RAI 6)

6. Clarify the second bullet in Section 10.1.6.4.5.

The second bullet in Section 10.1.6.4.5 is acceptable to the staff for neutron absorbing materials which receive 75% credit, but appears to permit wet chemistry to function as the primary method for determining ^{10}B in neutron absorbing materials receiving 90% credit as well, which would not be acceptable to staff.

For 90% credit of the neutron absorber towards k_{eff}, partial substitution of neutron attenuation acceptance tests by wet chemistry methods may be 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. If statistically significant comparative results between wet chemistry tests and neutron attenuation tests are provided, the staff may make a safety determination permitting the increased use of wet chemistry analysis as a substitution for neutron attenuation measurements.

An example of an adequate acceptance testing for a material receiving 90% credit would be the previously approved sampling plan for the MAGNASTOR: "The sampling plan shall require that each of the first 50 sheets of neutron absorber material from a lot, or a coupon taken therefrom, be tested. Thereafter, coupons shall be taken from 10 randomly selected sheets from each set of 50 sheets. This 1 in 5 sampling plan shall continue until there is a change in lot or batch of constituent materials of the sheet (i.e., boron carbide powder or aluminum powder) or a process change. A measured value less than the required minimum areal density of ^{10}B during the reduced inspection is defined as nonconforming, along with other contiguous sheets, and mandates a return to 100% inspection for the next 50 sheets."

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

NAC International Response

The second bullet is removed from Section 10.1.6.4.5 of the MAGNASTOR FSAR. This removes the alternate methods for ^{10}B testing and limits the testing to neutron attenuation. As this section pertains only to borated aluminum alloy and borated MMC absorbers and these

NAC International Response to RAI 6) (cont'd)

absorbers are listed as 90% credited in the fourth (now third) bullet, neutron attenuation testing is thereby the only acceptable test method.

The sampling plan for neutron attenuation testing referred to in the third paragraph of the RAI is retained within Section 10.1.6.4.5 of the MAGNASTOR FSAR.

December 2009

Revision 09C

MAGNASTOR®

(Modular Advanced Generation Nuclear All-purpose STORage)

FINAL SAFETY ANALYSIS REPORT

Docket No. 72-1031

NAC INTERNATIONAL

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Chapter 10

Chapter 10
Acceptance Criteria and Maintenance Program

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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, which may be composed of homogeneous or heterogeneous materials. The heterogeneous standard will be calibrated to a recognized standard (e.g., homogeneous material such as ZrB_2 plate material or a NIST-produced standard) or by attenuation of a thermal neutron beam correlated to the known cross-section of ^{10}B at the beam energies. 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.**

- **The ^{10}B areal density is measured using a collimated thermal neutron beam of up to 2.54 cm in diameter, with a tolerance of 10 percent.**

- **Based on the MAGNASTOR required minimum effective areal density of ^{10}B – 0.036 g/cm^2 for the PWR basket and 0.027 g/cm^2 for the BWR basket – and the credit taken for the ^{10}B for the criticality analyses, i.e., 90% for borated aluminum**

alloys and for borated metal matrix composites, a required minimum areal density for the as-manufactured neutron absorber sheets is established.

- Test locations/coupons shall be well distributed throughout the lot of material, particularly in the areas most likely to contain variances in thickness, and shall not contain unacceptable defects that could inhibit accurate physical and test measurements.
- The sampling plan shall require that each of the first 50 sheets of neutron absorber material from a lot, or a coupon taken therefrom, be tested. Thereafter, coupons shall be taken from 10 randomly selected sheets from each set of 50 sheets. This 1 in 5 sampling plan shall continue until there is a change in lot or batch of constituent materials of the sheet (i.e., boron carbide powder or aluminum powder) or a process change. A measured value less than the required minimum areal density of ^{10}B during the reduced inspection is defined as nonconforming, along with other contiguous sheets, and mandates a return to 100% inspection for the next 50 sheets. The coupons are indelibly marked and recorded for identification. This identification will be used to document the neutron absorber material test results, which become part of the quality record documentation package.
- The minimum areal density specified shall be verified for each lot at the 95% probability, 95% confidence level (also expressed as 95/95 level) or better. The following illustrates one acceptable method.

  The acceptance criterion for individual plates is determined from a statistical analysis of the test results for that lot. The minimum ^{10}B areal densities determined by neutron attenuation are converted to volume density, i.e., the minimum ^{10}B areal density is divided by the thickness at the location of the neutron attenuation measurement or the maximum thickness of the coupon. The lower tolerance limit of ^{10}B volume density is then determined—defined as the mean value of ^{10}B volume density for the sample, less K times the standard deviation, where K is the one-sided tolerance limit factor for a normal distribution with 95% probability and 95% confidence.

  Finally, the minimum specified value of ^{10}B areal density is divided by the lower tolerance limit of ^{10}B volume density to arrive at the minimum plate thickness that provides the specified ^{10}B areal density.

  Any plate that is thinner than this minimum or the minimum design thickness, whichever is greater, shall be treated as nonconforming, with the following exception. Local depressions are acceptable, as long as they total no more than

0.5% of the area on any given plate and the thickness at their location is not less than 90% of the minimum design thickness.

- **All neutron absorber material acceptance verification will be conducted in accordance with the NAC International Quality Assurance Program. The neutron absorber material supplier shall control manufacturing in accordance with the key process controls via a documented quality assurance system (approved by NAC or NAC's approved fabricator), and the designer shall verify conformance by reviewing the manufacturing records.**
- **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.**

10.1.6.4.6 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.

Open porosity for borated aluminum and borated MMC neutron absorber material must be no greater than 0.5% unless qualification tests are performed to ensure that blisters are not produced under submerging and subsequent vacuum drying conditions.

Chemical composition of the boron carbide powder must meet the requirements of Table 1 of ASTM C 750-03, Type 3. Additional chemical requirements, applicable to a particular absorber material, may be placed on the boron carbide powder as a result of the "key manufacturing process controls" invoked by Section 10.1.6.4.6. Additional requirements may include, but are not limited to, upper limits on fluorine and chlorine content.

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 dimension 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 performing the testing shall be trained and qualified in the process and in the test procedure.

Wet chemistry testing is performed by dissolving the aluminum in the matrix, including the powder and cladding, in a strong acid, leaving the B_4C material. A comparison of the amount of B_4C material remaining to the amount required to meet the ^{10}B content specification is made using a mass-balance calculation based on sample size.

A statistical conclusion about the neutron absorber sheet from which the sample was taken and that batch of neutron absorber sheets may then be drawn based on the test results and the controlled manufacturing processes.

The adequacy of the wet chemistry method is based on its use to qualify the standards employed in neutron blackness testing. The neutron absorption performance of a test material is validated based on its performance compared to a standard. The material properties of the standard are demonstrated by wet chemistry testing. Consequently, the

specified test regimen provides adequate assurance that the neutron absorber sheet thus qualified is acceptable.

Acceptance Criteria

The wet chemistry test results shall be considered acceptable if the ^{10}B areal density is determined to be equal to, or greater than, that specified on the fuel tube License Drawings. Failure of any coupon wet chemistry test shall result in 100% sampling, as described in the sampling plan, until compliance with the acceptance criteria is demonstrated.

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]. For Boral, a laminated absorber, yield strength credited in the structural analysis was limited to the outer aluminum cover sheets. Therefore, only the cover sheet must be shown to meet the required strength.

10.1.7 Thermal Tests

Thermal acceptance testing of the MAGNASTOR system following fabrication and construction is not required. Continued effectiveness of the heat-rejection capabilities of the system may be monitored during system operation using a remote temperature-monitoring system.

The heat-rejection system consists of convection air cooling where air flow is established and maintained by a chimney effect, with air moving from the lower inlets to the upper outlets. Since this system is passive, and air flow is established by the decay heat of the contents of the TSC, it is sufficient to ensure by inspection that the inlet and outlet screens are clear and free of debris that could impede air flow. Because of the passive design of the heat-rejection system, no thermal testing is required.

10.1.8 Cask Identification

Each TSC and concrete cask shall be marked with a model number and an identification number. Each concrete cask will additionally be marked for empty weight and date of loading. Specific marking instructions are provided on the license drawings for these system components.