October 13, 2005

Mr. Dallas D. Mayfield, Vice-President
Business Development
AAR Corporation
12633 Inkster Road
Livonia, Michigan 48150

SUBJECT: REQUEST FOR ADDITIONAL INFORMATION FOR REVIEW OF THE AAR TOPICAL REPORT (TAC NO. L23782)

Dear Mr. Mayfield:

By letter dated October 28, 2004, as supplemented on January 18, 2005, AAR Corporation (AAR) submitted a topical report to the U.S. Nuclear Regulatory Commission (NRC). The topical report requested NRC approval of 90% boron credit for BORAL.

In connection with the staff's technical review, we need the information identified in the enclosure to this letter. We request that you provide the information by January 6, 2006. Inform us in writing at your earliest convenience, but no later than December 23, 2005, if you are not able to provide the information by the requested date. You should also include a new proposed submittal date and the reasons for the delay to assist us in re-scheduling your review.

Please reference Docket No. 72-57 and TAC No. L23782 in future correspondence related to this request. The staff is available to meet and discuss your proposed responses. If you have any questions regarding this matter, I can be contacted at (301) 415-8500.

Sincerely,

/RA/

L. Raynard Wharton, Project Manager
Licensing Section
Spent Fuel Project Office
Office of Nuclear Material Safety
and Safeguards

Docket No. 72-57

Enclosure: Request for Additional Information

Mr. Dallas D. Mayfield, Vice-President
Business Development
AAR Corporation
12633 Inkster Road
Livonia, Michigan 48150

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AAR CORPORATION

DOCKET NO. 72-57

REQUEST FOR ADDITIONAL INFORMATION

RELATED TO THE AAR TOPICAL REPORT

CREDIT FOR 90% OF THE ^{10}B IN BORAL

By submittal dated October 28, 2004, as supplemented, AAR Corporation (AAR) requested approval of the AAR topical report, "Credit for 90% of the ^{10}B in Boral." The topical report proposes increasing the boron credit granted for BORAL from 75% to 90%.

This request for additional information (RAI) identifies additional information needed by the Nuclear Regulatory Commission (NRC) staff in connection with its review of this topical report.

Each individual RAI section describes information needed by the staff to complete its review of the topical report and to determine whether the vendor has demonstrated compliance with regulatory requirements.

Criticality

The following information is needed to determine compliance with 10 CFR 71.55, 71.59, and 72.124.

General Criticality Comments

1. Revise the assessment to concentrate on the neutron transmission probability and its effect on k_{eff}, and to address neutrons with energies above thermal.

   The report uses the percentage of absorption in the BORAL as a measure of the poison plate's effectiveness. The portion of incident neutrons that passes through the poison plate is a more important measure of effectiveness. The table presented on page 3 of of the topical report shows a small change in neutron absorption (i.e., approximately 0.50% to 0.05%) between the experimental and calculated absorption values for the 1/8-inch and 1/4-inch thick plates. However, when one considers the relative transmission rate, the difference between the experimental and calculated results is a change of approximately 3.5% to 6%. This large change in the number of neutrons available to cause a criticality is a significant consideration. This is particularly true when the system is close to the critical point.

   The topical report should address neutrons with energies above thermal. The absorption effectiveness of ^{10}B decreases rapidly with increasing energy and the channeling effect of neutrons with energies other than thermal should be addressed. For example, Figure 2 of Reference 14 provides experimental data regarding the amount of transmission for a BORAL sample of a given mesh size verses incident neutron energy. This plot indicates that if the neutron energy is increased from 0.1eV to 0.3eV, the transmission factor increases from 0.04 to 0.12 (300% increase) for a mesh size of 170, showing a nearly direct relationship between neutron energy and transmission. For many fuel storage and transport applications this is important to criticality safety because the fission contribution from neutrons above thermal energies is significant. An example is the benchmark LEU-COMP-THERM-51-19, where approximately 6.5% of the fissions are caused by neutrons between 0.625 and 1000 eV. The major question to address is, "If a BORAL poison plate has a minimum acceptable ^{10}B areal density of X, what would be the minimum acceptable ^{10}B areal density in a homogeneous poison plate that will give an equivalent value of k_{eff}"? Equivalency with a homogeneous poison plate is important because this is the way the poison plate is usually modeled in the criticality analysis of a design using BORAL. However, because transmission fraction is the closest representative property of a poison plate that can be measured in a practical sense and transmission is not highly sensitive to the specific cask design, it can be helpful to use this parameter in lieu of direct calculations of k_{eff}.

2. Make the distinction clear between the techniques used to fabricate BORAL today versus those used in the past.

   The conclusions of the report draw heavily on the particular fabrication techniques currently used to produce BORAL, which are in contrast to the techniques used in the past. Examples are: 1) the average size of the boron particles used today appears to be considerably smaller (50μ in diameter versus 80 to 200μ) than in the past, 2) passivation is now performed, 3) current rolling techniques tend to break particles apart more effectively than in the past, and 4) the current practice of loading the boron content significantly above the acceptable minimum target to assure that no coupons will test below the minimum acceptance level. These current techniques need to be specified and made a condition of any acceptance for 90% credit to the extent that they are part of the basis for justifying a credit allowance of 90%.

3. Provide a consistent table of data or a plot that compares the measured neutron transmission for BORAL samples of a given "true" aerial density (as measured by chemical assay), the measured neutron transmission for homogenous absorber plates of a given "true" aerial density, and the neutron transmission predicted by the Burris model. This data should use a consistant set of values for plate thickness, particle size, and ^{10}B enrichment.

   Figure 5-1 on page 19 and the corresponding text indicates that the 228 BORAL samples tested by NETCO (Northeast Technology Corporation) had a minimum required aerial density of 0.02 g/cm^2. Page 20 of the report then indicates that chemical assay determined that the mean aerial density of these samples was ~0.025 g/cm^2. Figure 5-8 on page 30 then indicates that a BORAL sample with a minimum certification of 0.02 g/cm^2 has a neutron attenuation factor of ~0.962 (transmission factor of 0.038). Chemical assays indicate that this sample would actually have 0.025 g/cm^2 of boron. Figure 5-8 indicates that this aerial density corresponds to a neutron attenuation of ~0.972 (transmission factor of 0.028) for a homogenous absorber. This difference between these two transmission factors results in a "channeling effect" of nearly 36% [(0.038-0.028)*100%/(0.028) = 35.71%]. This value is larger than the maximum value of

~14% shown in Figure 5-6, and much larger than the prediction of ~1.5% for an aerial density of 0.025 gm/cm^2.

Specific Criticality Comments

1. In the second paragraph in Section 2, item 2 states that the applicant must justify a request for 90% credit for the poison content in BORAL based on an analysis of the applicant's particular design.

   In consideration of the information provided in the topical report, it appears that the justification for taking 90% credit for the boron content in a BORAL poison plate will need to be established on a case-by-case basis. Case-by-case justification is necessary because of the need to establish equivalency between the value of k_{eff} in an applicant's particular design using BORAL plates and the k_{eff} in that design when the poison plates are modeled as having a homogeneous boron content. The topical report needs to be structured so as to assist the applicant in making the justification for 90% credit.

2. Provide the basis for the abundance value of 18.3 wt% ^{10}B in natural boron given in Section 3.

   Various references give different values for the ^{10}B abundance in natural boron. The abundance value should be a minimum bound of all sources of natural boron or be justified for the specific source of natural boron that AAR agrees to use for future production where 90% credit it requested.

3. Give the neutron beam size for the transmission measurements reported in the topical report such as the transmission tests reported in Section 5.2.

   As the beam size becomes larger, the transmission test becomes less sensitive to localized variations in the boron areal density.

4. Discuss the evidence for and the extent to which the new rolling process breaks up large particles and disperses particle fragments of B_4C, which are created during the rolling process.

   It is reported in Section 5.3 that B_4C particles are broken into smaller pieces during the rolling process. The particle fragments need to be displaced throughout the aluminum matrix during the rolling process to reduce their contribution to the channeling effect.

5. Provide the detailed calculation for the value of thermal neutron transmission (T) for 100 micron particles as reported on page 24, first sentence, last paragraph.

   The staff was unable to reproduce the result and confirm the calculational methodology. The last paragraph on page 24 needs to discuss the effect of larger particle size by comparing the transmission fraction rather than comparing the absorption percentage (See item 1 under the General Comments above).

6. Please address the evidence in Reference 29 that a streaming effect of approximately 25% (aerial density) was observed when the samples were corrected for actual aerial density verses minimum certified aerial density.

AAR uses statements, in part from Ref. 29, Gao's dissertation regarding modeling neutron attenuation properties that seem inconsistent with the original intent. [passages used in the AAR topical report are in bold];

Topical Report, Section 5, page 29
"**The good match of transmission coefficient curves of ZrB_2 and BORAL implied that when having the same ^{10}B aerial density, these two materials have the same neutron attenuation effect." And "in the above experiments, the streaming effect was not observed**. "

Reference 29, page 5-27
"**The good match of transmission coefficient curves of ZrB_2 and BORAL implied that when having the same ^{10}B aerial density, these two materials have the same neutron attenuation effect."**

Reference 29, page 5-29
"However, evidence from other researchers previous research [3][4][19] showed that neutron channeling exists in BORAL and with the same loading of ^{10}B, BORAL will give a higher transmission than a homogenous material. But **in the above experiments the streaming effect was not observed**. It was suspected that the certified aerial densities from Brooks & Perkins were effective aerial density and the actual loading was higher. "

Gao's dissertation proceeds to discuss physical measurements of the BORAL samples revealed that the ^{10}B density in the core was actually 0.191 g-10B/cm^3 verses the reported value of 0.156 g-10B/cm^3. This 22.3% increase in aerial density is therefore required to produce the same transmission coefficient in BORAL verses a homogenous absorber and corresponds well to measurements made by others (Ref. 23 of the AAR topical report). If the data in Figure 5-7 is used to determine the percent change in transmission coefficient between 20 and 25 mg^{10}B/cm^2, the resulting value is approximately 100% [(0.06-0.03)/(0.03)]. This would indicate that for a 25% density difference the transmission coefficient doubles. This is dramatically larger than the 1-2% increase in transmission predicted by Figure 5-6.

The data in Figure 5-6 suggest that at a minimum the proper amount of credit may depend on areal density. In addition, other factors may be important such as average particle size.

7. Confirm that the figure referenced in the second paragraph on page 30 of the topical report is correct.

It appears that the reference should be Figure 5-8 rather than 5-7.

Materials

The following information is needed to determine compliance with 10 CFR 72.122 and 72.124.

1. Explain why consensus standards such as, the American Society for Testing and Materials (ASTM), American Nuclear Society (ANS), or American National Standards Institute (ANSI), have not been referenced for either the fabrication or the testing of the BORAL.

   For example, no specification has been provided for the B_4C feed material, chemical analysis, density determination, etc. Using an ASTM specification (or equivalent) for a nuclear application would ensure that the material has the necessary characteristics and properties to perform its design functions during the service lifetime.

2. Provide the tests conducted by each of the cask designers (e.g., NAC, Holtec, TN, etc).

   The abstract (page iii of the topical report) clearly states the cask designers have tested BORAL and confirmed the safety and durability of BORAL in their specific dry spent fuel storage systems. Further, page 13 states that AAR has been advised by the cask suppliers that no blisters have occurred under test conditions representing the most demanding design and operating conditions. NRC is only aware of the test program performed by NETCO on BORAL. What are the technical bases for these statements?

3. Describe the procedures for extracting the moisture after the Boral has been submersed at 125 psi or other hydrostatic pressures.

   This is to provide the assurance that moisture absorbed by the BORAL pores can be extracted from the as-dried BORAL before it is placed into service.

4. Justify the use of calibration coupons other than ZrB_2.

   Appendix B implies that calibration coupons other than ZrB_2 may be used in transmission testing. ZrB_2 is a compound at the molecular level and is expected to have greater homogeneity than borated materials produced by other means. From the information given in the references it seems that a ZrB_2 compound was used as the SRM in some places and in other places the SRM was an Al/B_4C composite material.

5. Provide the justification that the BORAL suffers no degradation as a neutron absorber after extended exposures to temperatures that are above and for times that are greater than those used in the proposed dry storage service conditions (i.e., drying 570EC and storage 400EC).

   Reference 32 does not seem to present such data except for lower temperatures.

6. Justify that the edge materials are not deficient due to the presence of cracks in the as-rolled BORAL product.

It is well known that the edge cracking or tendency to split increases as the B_4C content is increased in the composite material of Al/B_4C. BORAL has a particularly high B_4C content that is well within the range at which cracking predominates for high B_4C content composites rolled at lower temperatures. These cracks or splits can be problematic in a material that must provide uniform absorptive properties for all areas of the plate.

7. Clarify whether AAR plans to use 6061 aluminum alloy powder as the matrix of the BORAL for which 90% credit is requested.

   If 6061 is used, it must be justified and qualified as homogeneous and durable under expected lifetime thermal and neutron exposure conditions. On page 17, a statement is made that the use of 6061 alloy powder does not alter the effectiveness of BORAL-6000. It is important that BORAL-6000 has been qualified before its use.

8. Clarify whether or not AAR is increasing or decreasing the weight (or volume) percentage of B_4C in BORAL.

   The abstract (page iii of the topical report) clearly states, “increasing the ^{10}B credit from 75% to 90% will reduce the amount of B_4C required,” which will provide AAR more flexibility in the design and continued improvement of BORAL, while maintaining a conservative margin for criticality safety. This statement appears to be inconsistent with Reference number 32 which implies that the B_4C has been increased to facilitate the prevention of blisters from discussion with the applicant. In fact, page 1 of the topical report indicates 40-65% B_4C in the core.

9. Justify the size of the sample that is used to determine if mixing is adequate and justify the use of one random sample from every blended powder batch for chemical testing as stated on page 9 of the topical report. What exactly does the sample tell about the batch?

   The applicant would need to justify that this practice is statistically acceptable or that it is done in accordance with some standard practices used in industry, e.g., ASTM E105, Standard Practice for Probability Sampling of Materials, or some more appropriate standard.

10. Clarify what was meant by “only natural boron will be used and enriched boron will not be used for this application.” Clarify what percent ^{10}B is assumed in calculations–the mean in Figure A-3 of the Topical Report is given along with values ranging from 18.35 to 18.64.

    Staff is familiar with the equations on page 8 and how they are used by industry. However, the computation of the areal density in the product requires knowledge of the fraction of ^{10}B in the enriched boron in order to determine an accurate areal density of ^{10}B.

11. Indicate the number of samples evaluated from a lot and indicate the test method (i.e., microscopy) used to determine the particle size of the B_4C in the core after rolling. Give statistical parameters that were obtained from quantitative examinations, i.e., metallography/microscroscopy (QM). If QM was used, indicate the number of particles for various segments (particle sizes) within the overall distribution. For example, give

the values for the numbers of particles greater than 50 microns, at less than 50 microns, etc. Submit a few metallographic samples of current production so that confirmatory measurements can be conducted by the NRC staff.

Page 18 of the topical report states that after rolling, the average B_4C particle size in BORAL is about 50 microns. This particle size is smaller than the particle size that caused significant channeling between particles. No evidence has been provided to support 50 microns particle size, hence, the staff is unable to verify the accuracy of this value.

12. Explain why the BORAL has not undergone any mechanical testing to demonstrate durability. It would be expected that mechanical tests would give benchmarks that could be used to test for processing variables and their effects or for testing the effects of exposure to environmental conditions (thermal or radiation). Because significant changes have been made in processing of BORAL, demonstrate that this has not had significant effects on the mechanical properties when compared with the BORAL material previously approved at the 75% credit level.

    A change in process controls could adversely affect mechanical properties. For example, by increasing the boron content over that qualified by testing, or decreasing the powder metal compact density, etc., properties may be altered in a manner that could require re-qualification by applicable testing.