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AAR CARGO SYSTEMS

a division of AAR Manufacturing Group, Inc.

April 30, 2004

Mr. Stewart Brown
Mail Stop: 013D13
U.S. Nuclear Regulatory Commission
One White Flint North
11555 Rockville Pike
Rockville, MD 20852-2738

Subject: Aluminum Powder Specification Revision for BORAL Neutron Absorber

Dear Mr. Brown:

The purpose of this letter is to advise the NRC of a planned revision in the specification for BORAL, subject to the successful completion of the manufacturing verification program as discussed herein. The revision provides for the option to use a stronger aluminum alloy in the manufacturing of BORAL used in dry spent fuel storage casks and canisters, and has no adverse impact on safety.

Background

BORAL is a thermal neutron absorber manufactured by AAR Manufacturing, a division of AAR Corporation located in Livonia, MI. BORAL is a laminated composite material made with 1100 series aluminum clad enclosing an inner core of compacted 1100 series aluminum and boron carbide (B_4C) powders. BORAL is manufactured by the following process:

- The aluminum and B_4C powders are blended based on the weight % of B_4C required to meet the customer specified areal density of the ^{10}B isotope
- The blended powder is packed into an aluminum box (ingot)
- The ingot is heated according to a proprietary heating profile
- The ingot is hot rolled to the customer's specified thickness
- The rolled sheets are sheared to finished sheet dimensions
- The sheets are visually inspected and chemical and/or attenuation tested to verify the presence of the required B_4C content

The hot rolling process compresses the Al/B_4C powders into a cermet with a density about 90-95% of the theoretical density of the composite. Most of the porosity in the core is in the form of small voids in the cermet, but some is interconnected, forming micro-pathways into the core.

In spent fuel pool applications, there have been occasional occurrences of blisters forming in the cladding of BORAL. Blisters can form from water which penetrates into the core through the interconnected porosity and reacts with exposed aluminum powder surfaces in the core to form aluminum oxide, Al_2O_3, and hydrogen. Usually the hydrogen gas escapes from the core through the porosity. However, in some cases, the growth of Al_2O_3 can restrict or

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close off pathways and trap hydrogen in a void space. If enough hydrogen accumulates, the pressure causes the clad to separate slightly from the core, causing a blister. The blisters are generally no larger than the diameter of a quarter and no more than 1/8 inch high. There have been numerous tests and evaluations performed on blisters by AAR, utilities, and other organizations which have found the BORAL core under blisters remains intact with no reduction in the core's ability to absorb thermal neutrons.

In dry fuel storage canisters and casks, the spent fuel canister is not in the pool water long enough for the oxidation process to close the porosity in the BORAL core. Testing by cask designers has shown that the water will easily escape from the BORAL core when the temperature inside the canister increases during vacuum drying. When exposed to very high heat-up rates (much higher than the canister/cask system design basis) in test programs, water in the BORAL core can flash to steam and cause a steam blister. Steam blisters created in tests are generally larger than hydrogen blisters and indicate that steam blisters could potentially interfere with fuel retrieval when the fuel is eventually removed from the canister/cask.

To add more conservatism to the BORAL design and greater assurance that steam blisters will not occur, in June 2003, AAR initiated a BORAL Improvement Program with the specific objective of developing a blister-resistant BORAL product.

BORAL Improvement Program

Several process and material modifications were identified, evaluated, and tested. One R&D program was to test different aluminum alloy powders. We reviewed the properties of various alloys and selected two alloys which have properties that we felt would benefit BORAL (i.e., higher strength than 1100, good corrosion resistance, and good formability): a 4000 series (high silicon) alloy and 6061 (magnesium and silicon) alloy. We developed a "test-to-failure" test to determine if BORAL made with the alloy powders were more resistant to blisters. This test has 2 steps: (1) soak a sample in hot (170°F) de-mineralized water for at least 30 days (enough time for the oxidation process to confine water inside the BORAL core), and (2) remove the sample from the water and place it in an oven heated to approximately 500° F, which will flash the water to steam. With the current BORAL materials, steam blisters will form within minutes.

We made samples with each alloy powder at the same time as control sheets with 1100 series powder, using the same B_4C wt % and the same manufacturing processes. We cut samples from each sheet, soaked all the samples in the same tank for the same length of time, and then placed a set of one of each of the samples in the oven. We performed 4 separate tests at different times, testing a total of 12 samples for each powder. All of the regular BORAL samples blistered. Both of the alloy powders performed much better: only one of the 6061 alloy samples had a blister, and 2 of the 4000 series alloy samples had one blister each.

Conclusion

Based on material properties, the results of AAR tests, and the extensive NRC licensing history for other neutron absorbers using 6000 series aluminum, AAR has selected 6061 alloy powder to make a blister-resistant BORAL product, which is designated as BORAL-6000. The only significant difference between current BORAL and BORAL-6000 is the greater strength and durability (resistance to blisters) of BORAL-6000. There is no difference in the neutron absorption capability, or the effect of service conditions (temperature and radiation effects) on the two materials.

The chemical composition of 1100 and 6061 aluminum alloys are shown in Attachment 1.

Manufacturing Verification Plan

AAR will perform a manufacturing verification program to confirm manufacturability, process controls, repeatability, product performance, and quality. This program will include:

- A supplementary audit of our aluminum powder supplier to qualify the process to make the 6061 alloy powder.
- At least one complete demonstration production run for one commercial size powder batch (which will make 20 PWR or 30 BWR size sheets), including: powder mixing and QA verification of satisfactory blending of the powders; packing the powders in ingots and verification of packed density; heat-up; rolling; annealing; shearing; conformance with dimensional requirements; and chemical testing of samples taken from each sheet to verify the ^{10}B areal density in the final product.
- Verification of uniform ^{10}B distribution in a final sheet by chemical testing at least 20 samples from random locations in a sheet.
- Performance testing by subjecting samples to extreme conditions known to cause failure in standard BORAL sheets to verify improved resistance to blisters.
- BORAL-6000 will meet all of the current QA requirements for BORAL.

The material properties of 6061 aluminum are well known and equal or exceed the critical properties for 1100 series aluminum for this application. AAR's manufacturing processes are well established and will assure that the ^{10}B in BORAL-6000 will be uniformly distributed. Upon successful completion of the manufacturing verification plan, AAR intends to modify its aluminum powder specification to include the option for using 6061 alloy powder. No other tests are planned, unless recommended by the NRC.

If you have any questions or comments, please contact me at 734-466-8210.

Sincerely,

Jim Hobbs

James S. Hobbs
Director Nuclear Programs

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ATTACHMENT 1

Chemical Composition of 1100 and 6061 Aluminum Alloys

	Composition (wt %)	
Element	**1100 Series**	**6061 Alloy**
Al	99.00 (min)	Remaining
Si	0.95 (Si+Fe)	0.40-0.80
Fe	0.95 (Si+Fe)	0.70 (max)
Cu	0.05-0.20	0.15-0.40
Mn	0.05 (max)	0.15 (max)
Mg	- -	0.80-1.2
Cr	- -	0.04-0.35
Zn	0.10 (max)	0.25 (max)
Other	0.15 (max)	0.15 (max)

Reference: "Aluminum and Aluminum Alloys", ASM International Specialty Handbook, 1993