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March 22, 2002

Ms. Rebecca Karas
Project Manager
Spent Fuel Project Office
United States Nuclear Regulatory Commission
11555 Rockville Pike
Rockville, MD 20852

Subject: Summary of NAC Boral Testing Program

Reference:
1. NAC Letter QA20010095, Smith to McGinty, February 5, 2001, re: Evaluation results for ENSA Fuel Tube Pressure Testing
2. Conference Call, Smith, Pennington & Danner to Karas. August 10, 2001, re: ENSA Fuel Tube Boral Blisters
3. NAC Letter QA20010537, Smith to Karas, September 7, 2001, re: Boral Deformation (Blistering)
4. Conference Call, Thompson to Karas, February 21, 2002, re: NAC Boral Test Program
5. Conference Call, Thompson to Karas, March 8, 2002, re: NAC Boral Testing Report

Dear Ms. Karas:

In accordance with the Reference 5 conference call discussions, NAC International (NAC) herewith submits a non-proprietary summary report, "Evaluation of the Structural Fitness of Boral for Use in NAC Spent Fuel Canisters," on the Boral testing recently completed by NAC.

Also, please note that NAC moved its corporate offices in mid-February. The new address is:

NAC International
3930 East Jones Bridge Road
Norcross, GA 30092

Please contact me if you have any questions or require any additional information.

Sincerely,

T C Thompson

Thomas C. Thompson
Director, Licensing
Engineering & Product Development

Enclosure

NMSS01 Public

ED20020142

Evaluation of the Structural Fitness of Boral™ for Use in NAC Spent Fuel Canisters

March 2002

NAC INTERNATIONAL

Evaluation of the Structural Fitness of Boral™ for Use in NAC Spent Fuel Canisters

NAC International (NAC) has recently completed a comprehensive testing program to evaluate the structural fitness of Boral™ for use in NAC's PWR spent fuel storage and transportation canisters. The testing program included nine separate tests that represented, or exceeded, the maximum design basis conditions that the Boral™ will experience during actual canister operations. Based on the test results, NAC has concluded that Boral™ is structurally stable and will perform its function as a neutron absorber under all canister operating conditions.

Boral™ is manufactured and supplied by AAR Cargo Systems of Livonia, Michigan. Boral™ is a composite laminate material that is used as a neutron absorber for criticality control in NAC's spent fuel dual-purpose canisters and spent fuel transportation casks. The outer layers (cladding) of Boral™ are series 1100 aluminum, which enclose a core mixture of series 1100 aluminum powder and B_4C powder.

The NAC Boral™ testing program was initiated as a result of "blistering" that occurred on Boral™ sheets used in the Dual-Purpose Trillo (DPT) cask fabricated by NAC's licensee in Spain, Equipos Nucleares, S.A. (ENSA), for its customer, Empresa Nacional de Residuos Radiactivos, S.A. (ENRESA). The blisters are deformations of the outer aluminum cladding. ENSA reported to NAC in August 2001 that blisters were found on several Boral™ sheets after performing acceptance tests for the first DPT cask. At a later date, ENSA disassembled all of the fuel tubes and determined that blisters were present on a total of 11 sheets, which were located in 10 different fuel tubes.

The testing sequence performed by ENSA included the following test conditions and operational steps:

Hydrostatic Tests

The cask with basket was pressurized at 18 psig for a period of 40 minutes; atmospheric pressure for 12 hours; pressurized to 131 psig for 10 minutes; then reduced to 101 psig for 30 minutes.

Drying

After the hydrostatic tests were completed, the cask was opened and the basket was taken out of the cask to dry. Accessible areas of the basket assembly were manually dried using dry cloth. The basket was exposed to natural air drying for six days prior to vacuum drying.

Vacuum Drying

The basket was replaced in the cask, and the cask was vacuum dried for 24 hours at ambient temperature. Following the 24 hours of vacuum drying, a vacuum of 11 mbar was held for 10 minutes with no pressure increase.

Thermal Test

Twenty-one heaters with a heat output of 1.285 kW each (total heat output of 27 kW) were used to heat the cask. The duration of the heat-up was 44 hours. The temperature was measured by two thermocouples located in two fuel tubes near the center of the basket, approximately halfway down the tube length. The maximum temperature, measured at the center of the basket, at completion of the thermal test was 438°F.

The blisters were the result of pressure in the Boral™ core. ENSA initially postulated that the blisters were caused by hydrogen generated by a chemical or galvanic reaction. NAC's theory was that water was forced into the relatively porous Boral™ core during the high-pressure hydrostatic tests, and the water flashed to steam during the thermal test. After conducting independent testing programs, both ENSA and NAC now believe the blisters were caused by steam pressure. The steam most likely resulted from localized high heat-up rates.

In response to the blistering occurrence at ENSA, NAC initiated a comprehensive test program to assess the structural fitness of Boral™ for its function as a neutron absorber in NAC's spent fuel storage/transportation canisters. Note that the Boral™ used in the DPT cask is thicker than the Boral™ used in the NAC-MPC and NAC-UMS® PWR canisters (0.10 inch for the DPT cask, 0.075 inch for the MPC/UMS®), and the DPT acceptance test parameters were much different from the conditions that Boral™ will be exposed to during NAC spent fuel canister operations. Since NAC was fabricating and delivering canisters to its customers, this NAC Boral™ testing program was designed specifically to evaluate and qualify Boral™ for use in the NAC-MPC and NAC-UMS® PWR canisters. The testing program simulated the operating environments, with conservative margins, that Boral™ will experience during actual canister loading and closure operations for NAC spent fuel canisters.

NAC's Project Plan for the evaluation defined the objectives for the testing program as:

- Identify any physical changes in Boral™ sheets when subjected to the conditions experienced in the operations and testing of spent fuel storage/transportation canisters.
- Determine if the conditions typically experienced in loading, pressure testing and drying a spent fuel canister could lead to blistering, deformation, delamination or other changes that could reduce the functional effectiveness of the Boral™ sheets used in the NAC-MPC or NAC-UMS® systems.
- Obtain results and backup data to support NAC's evaluation of the structural fitness of Boral™ to perform its intended function.

The NAC testing program was designed to determine if Boral™ is structurally capable of withstanding the environmental conditions inside an NAC PWR spent fuel canister. The most severe conditions occur while the fuel is being loaded in the canister in the spent fuel pool and during the canister closure, draining and drying operations. These conditions include: water pressure during fuel loading (for a 40-foot deep pool, the water pressure at the bottom is 17.3 psig); the hydrostatic pressure test of the shield lid weld of 21 psig; and the heat-up of the

Boral™ after the water is drained from the canister and the canister is vacuum dried (maximum of 30°F/hr for design basis fuel of 23 kW/canister). The tests were designed to simulate the design basis limits as described in the applicable NAC-MPC and NAC-UMS® Final Safety Analysis Reports (FSARs). Significant margins were added to the test values to assure conservatism. The conditions that occur during the fuel loading and canister closure operations were evaluated and were found to bound any other conditions during normal interim storage at the ISFSI or during normal transport conditions.

The testing program was implemented in three phases:

Phase 1 – Engineering Tests

Seven engineering tests were performed. The test samples included bare Boral™ sheet segments (approximately 8 inches x 8 inches) and Boral™ enclosed in stainless steel "panels." The panel is a mock-up of a fuel tube wall, fabricated in a manner similar to the NAC fuel tube design for Yankee Rowe and Connecticut Yankee (continuous weld around the sheath with clipped corners). These tests were performed to establish test parameters and procedures for the later Quality Assurance (QA) Program-compliant tests and to develop benchmark data to verify the reasonableness of the QA test results. The samples used in the engineering tests included Boral™ material with different characteristics, such as passivated samples and samples with different thicknesses and different boron areal densities. The tests focused on the specific Boral™ thickness that is used in NAC PWR canisters, although two of the engineering tests included samples of the thicker ENSA Boral™ sheets. The tests showed that Boral™ absorbs water when subjected to hydrostatic pressure, but all of the water escapes when the Boral™ is heated at the maximum design heat-up rate. None of the engineering tests, including tests at heat-up rates significantly higher than the maximum design basis, caused blisters or other deformation in the bare samples or enclosed Boral™ sheets.

Note that the engineering tests were considered informational and were not required to meet all NAC Quality Procedure requirements. However, each Phase 1 test was governed by an NAC prepared test procedure and was performed in accordance with the QA program of the testing organization.

Phase 2 – QA Compliant Tests of Boral™ Sheet Samples

The Phase 2 testing was the data verification step. Four Boral™ samples, approximately 8 inches x 8 inches, were used. The test parameters and sequence were similar to Phase 1 tests. The purpose of the Phase 2 tests was to verify the performance data of Boral™ in a QA compliant test. The samples were taken from the working inventory of material used in the Maine Yankee project (a standard NAC-UMS® PWR design). This material is similar to the Boral™ that will be used in the NAC-MPC canister projects (Yankee Rowe and Connecticut Yankee). The Phase 2 tests were performed at greater-than-design-basis hydrostatic pressure and heat-up rates. No blisters or other deformation occurred in the Phase 2 samples. The Phase 2 tests verified the data compiled in the engineering tests and confirmed the structural integrity of Boral™ in canister operating conditions.

Phase 3 – QA Compliant Test of an Enclosed Boral™ Sheet

The Phase 3 test was the acceptance test of the structural performance of Boral™ in the most conservative NAC PWR fuel tube design configuration. The fabricated panel represents the side of a fuel tube. The panel was made of a Boral™ sheet, approximately 42 inches long, enclosed in a stainless steel sheath. The sheath is identical to the cover sheath used in the fuel tube. The sheath is continuously welded to a backing plate (the backing plate is thicker than a fuel tube wall for stability and ease of handling) and has clipped corners, proportionately sized, that model the design of the Yankee Rowe and Connecticut Yankee NAC-MPC fuel tubes. Testing of the continuously welded sheath is considered to envelop the NAC-UMS® stitch weld design, since the continuous weld is more restrictive of water/steam flow and potentially could have a higher backpressure within the sheath.

NAC analyzed the effect of the cover sheath on the ability of water/steam to escape from the Boral™ in the fuel tube configuration in NAC Calculation EC 455-9564, "Boral Blister Investigation – Technical Justification of Scale Model Test Specimen." The calculation analyzed the pressure increase resulting from vaporization of the trapped water in the Boral™ and the stainless steel cover sheath and concluded that the cover sheath does not restrict the flow of water from the enclosed Boral™ sheet in a fuel tube. The vaporization pressure poses no threat to the integrity of the Boral™ or the fuel tube structure. The calculation also provides the justification of using a scale model section to approximate the performance of the fuel tube design.

The conclusion of Calculation EC 455-9564 was verified by the results of two separate engineering tests using enclosed Boral™ (in two different ovens, one under a vacuum), as well as the Phase 3 QA test. After the first panel engineering test, the cover sheath was removed and the Boral™ sheet was visually examined. There were no blisters or other deformation the Boral™. The second panel tested in an engineering test was kept intact to show the sheath condition after testing (no damage or deformation). The Phase 3 test, performed in accordance with the applicable provisions of NAC's QA program, was the acceptance test for the NAC-MPC/UMS® fuel tube design. The cover sheath on the Phase 3 panel was removed and the Boral™ sheet was visually examined. There were no blisters or other deformation to the Boral™.

The results of the extensive testing program performed by NAC demonstrate that Boral™ is structurally stable under the conditions that the Boral™ will experience during NAC canister operations. Tests at values well above the maximum operating values confirmed that adequate material performance margins exist.