Gamma Spectroscopy Measurements of BoroBond™ Blocks

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INTRODUCTION

A Rackable Can Storage Box (RCSB) has been proposed for use in the storage of highly enriched uranium (HEU) in the HEU Materials Facility (HEUMF) at the Y-12 National Security Complex. The RCSB is designed to provide efficient, safe, and secure storage of HEU. More detailed nuclear criticality safety goals as well as preliminary design sketches are provided in [1,2]. The RCSB will use Eagle-Picher Technologies BoroBond4™ (4.1 weight percent $^{nat}B_4C$) as the filler material. BoroBond™ is a borated, chemically-bonded, phosphate-based ceramic solid formed from an exothermic chemical reaction:

$$MgO(powder) + KH_2PO_4(powder) + 5H_2O(liquid) \rightarrow MgKPO_4 \cdot 6H_2O(solid)$$

Fly ash and B_4C powder may be added in varying proportions in order to produce a neutron-absorbing material. In order to characterize the material, BoroBond™ blocks of varying boron concentration, thickness, and water content were studied using prompt gamma neutron activation analysis (PGNAA) techniques.

DESCRIPTION OF WORK

For this work, four sets of test blocks, with 8 blocks in each set, of varying boron concentration and thickness were provided in order to investigate boron concentration sensitivity as a function of boron and hydrogen concentration and block thickness. Nominal block dimensions were 12x12x2 inches and 12x12x4 inches with nominal $^{nat}B_4C$ concentrations of 0, 2.3, 4.6, or 9.1 weight percent.

The boron capture process depends on both the boron and water content, and different boron and water contents can produce the same neutron captures in boron. After an initial set of measurements, half of the blocks were baked at 140°C for approximately 24 hours in order to reduce the water content and thus, vary the hydrogen concentration. Measurements would then be considered for use as boron concentration calibration standards for the RCSB material. Additional goals for this series of measurements included identification and quantification of hydrogen and other BoroBond™ materials. PGNAA techniques as well as gamma spectroscopy for gammas produced by the inelastic scattering of neutrons from BoroBond™ constituents were employed in this study. Herein, we report only the results of PGNAA of boron concentration.

Fig. 1 presents the arrangement of (6) ^{252}Cf pellet sources, a 4x4x4 inch tungsten alloy block, and a high-purity germanium (HPGe) detector against a 12 inch block. The tungsten block provided a high-density shield for lowering ^{252}Cf source gamma flux at the HPGe detector.

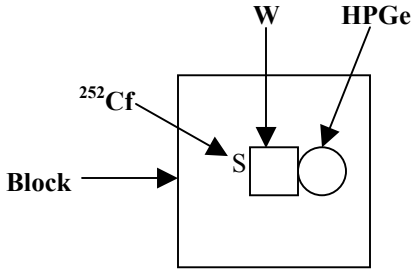

Fig.1 Experimental arrangement (side view).

This arrangement of source and detector can also be used adjacent to the RCSBs.

RESULTS

Combinations of the 2 and 4 inch unbaked blocks for a given boron concentration were measured to characterize samples of various thicknesses. Mean values of the detected 478 keV gamma from neutron capture in boron are presented in Fig. 2. Asymptotic behavior of peak counts for all boron concentrations occurred at approximately a 6 inch thickness. While the A series blocks were nominally 0 wt% boron, measurements indicated some level of boron was in the blocks.

After baking half of the blocks to 140°C for 24 hours, measurements were repeated for all block combinations. It was estimated that baking to 140°C would release ~ 5/6 of the water

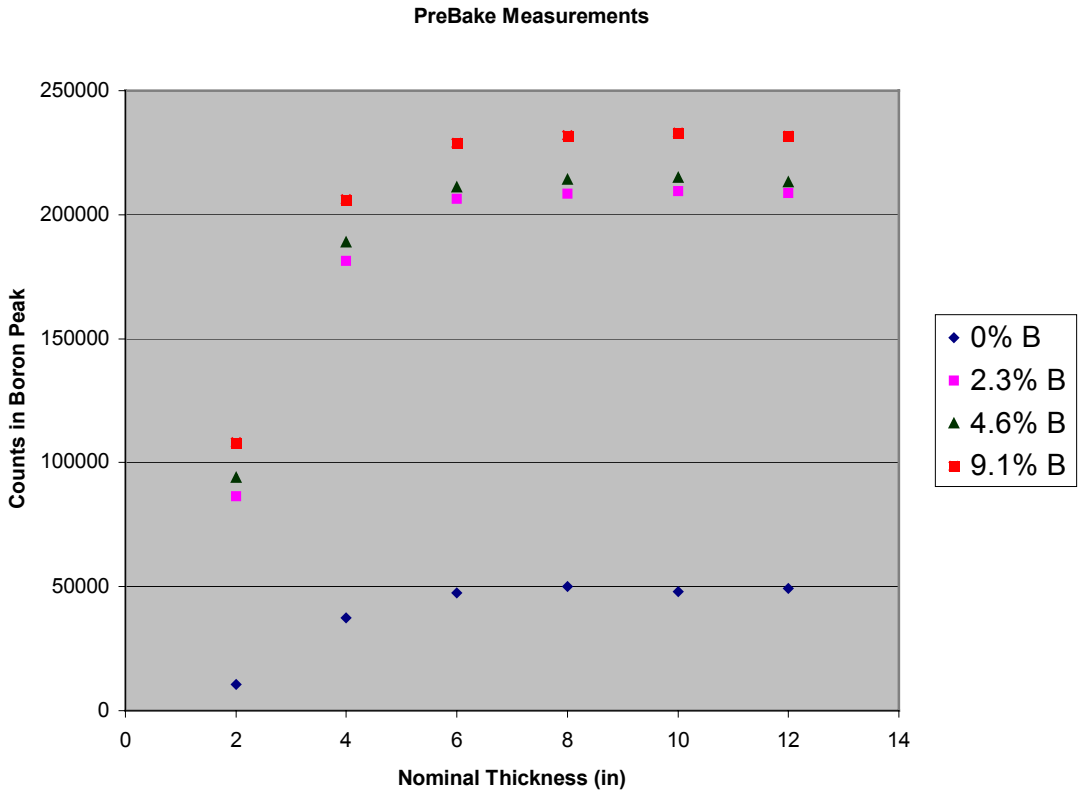

Fig. 2. Counts in boron peak as a function of nominal thickness.

in the ceramic blocks. The baked A-series blocks (0 wt% boron) showed no boron peak due to reduced neutron thermalization and only trace amounts of boron. Again, asymptotic behavior of peak counts for all boron concentrations occurred at approximately a 6 inch thickness.

PGNAA measurements of Borobond™ blocks have led to a method for quantifying $^{nat}B_4C$ content knowing the water content of the blocks from time-of-flight transmission measurements[3]. These time-of-flight measurements were sensitive only to water content. Future work will examine the capabilities of other gamma ray detectors (e.g. NaI) for this application and the use of an AmBe source with longer half life.

ACKNOWLEDGEMENT

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