Neutron Counting 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:

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

Ceramic water content provides neutron moderation while 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 thermal and epithermal neutron counting 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 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. 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.

The total neutron count rate and the epithermal neutron count rate in ${}^{3}He$ proportional counters was measured for both the baked and unbaked blocks. These count rates are related to the thermal and epithermal neutrons that are available to induce fission in uranium stored in RCSBs. Thermal, epithermal and total neutron count rates depend on both the boron and water content

Source neutrons for these measurements were provided by six ${}^{252}Cf$ pellet sources and a ${}^{252}Cf$-plated ion chamber source with total neutron outputs of 1.94e6 neutrons per second and 3.94e6 neutrons per second, respectively. The experimental arrangement of the source and detectors for neutron counting is shown in Fig. 1.

RESULTS

Fig. 2 presents average total count rates plotted as a function of block thickness for the unbaked blocks. For the baked blocks, the count rates are reduced by approximately an order of magnitude for the thinner blocks with no B_4C. Reduced water content results in less low energy neutrons, because the primary neutron slowing material (H_2O) is reduced to ~1/6 of the original value for the unbaked blocks. There are a variety of competing effects that are different at different thicknesses and B_4C contents and make this data useful for verifying calculations.

The thermal neutron count rates were obtained by subtracting the count rates from the detector covered with 0.045-in.-thick cadmium (detector 2) from those for the bare detector (detector 1) 4.875 in. away but symmetrically located with respect to the sources and blocks. The thermal, epithermal, and total count rates depend on both the water and B_4C content of the BoroBond™. It follows that these measurements alone cannot be used to obtain both quantities. Knowing the water content from another measurement (fast neutron transmission), would allow determination of the B_4C content.

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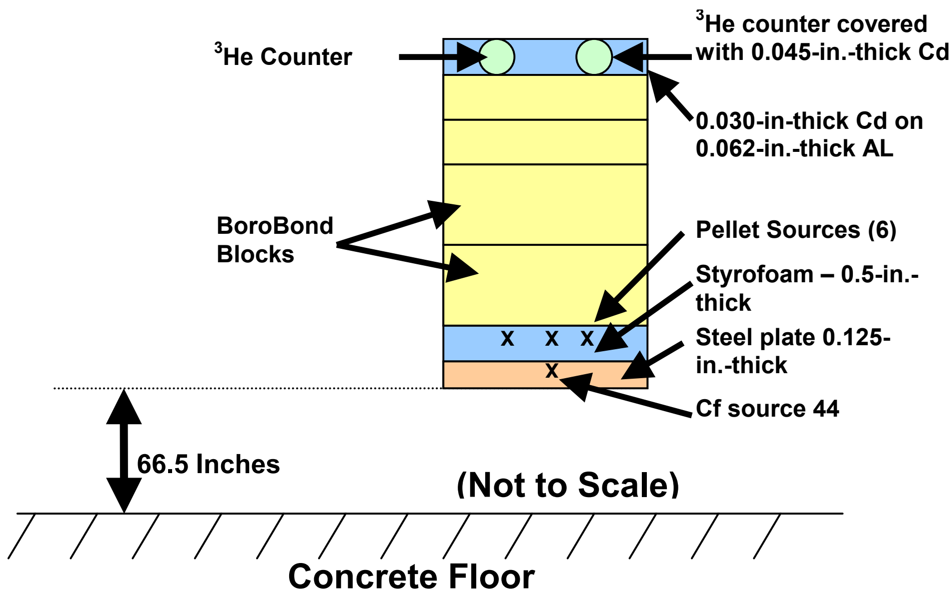

Fig. 1. Sketch of the source-detector block configuration for the neutron counting measurements.

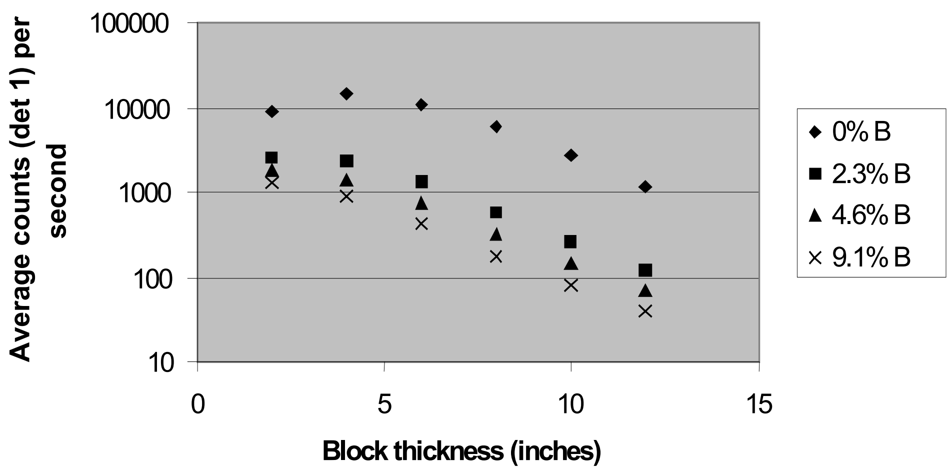

Fig. 2. Average count rate in detector 1 for unbaked blocks and varying B_4C content as a function of block thickness.

REFERENCES

1. A. W. Krass, K. D. Lewis, J. J. Lichtenwalter, D. A. Tollefson, "Comparison of Absorber Materials for a Palletized Rack Storage System," *Trans. Am. Nucl. Soc.*, 85, 159 (2001).
2. J. J. Lichtenwalter, D. A. Tollefson, L. E. Johnsen, A. W. Krass, K. D. Lewis, "Palletized Rack Storage System Absorber Material Testing," *Trans. Am. Nucl. Soc.*, 85, 161 (2001).