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Standard Guide for Establishing Surveillance Test Program for Boron-Based Neutron Absorbing Material Systems for Use in Nuclear Spent Fuel Storage Racks¹

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1. Scope

1.1 This guide provides guidance for establishing a surveillance test program to monitor the performance of boron-based neutron absorbing material systems (absorbers) necessary to maintain sub-criticality in nuclear spent fuel storage racks in a pool environment. The practices presented in this guide, when implemented, will provide a comprehensive surveillance test program to verify the presence of sufficient neutron absorbing material within the storage racks. The performance of a surveillance test program provides added assurance of the safe and effective operation of a high-density storage facility for nuclear spent fuel.

1.2 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:²

- C992 Specification for Boron-Based Neutron Absorbing Material Systems for Use in Nuclear Spent Fuel Storage Racks
- C1068 Guide for Qualification of Measurement Methods by a Laboratory Within the Nuclear Industry
- D412 Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension
- D430 Test Methods for Rubber Deterioration—Dynamic Fatigue
- D518 Test Method for Rubber Deterioration—Surface

Cracking (Withdrawn 2007)³

- D813 Test Method for Rubber Deterioration—Crack Growth
- D1415 Test Method for Rubber Property—International Hardness
- D2240 Test Method for Rubber Property—Durometer Hardness
- D3183 Practice for Rubber—Preparation of Pieces for Test Purposes from Products
- D4483 Practice for Evaluating Precision for Test Method Standards in the Rubber and Carbon Black Manufacturing Industries
- E6 Terminology Relating to Methods of Mechanical Testing
- E8 Test Methods for Tension Testing of Metallic Materials
- E23 Test Methods for Notched Bar Impact Testing of Metallic Materials
- E74 Practice of Calibration of Force-Measuring Instruments for Verifying the Force Indication of Testing Machines
- E290 Test Methods for Bend Testing of Material for Ductility
- G1 Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens
- G4 Guide for Conducting Corrosion Tests in Field Applications
- G15 Terminology Relating to Corrosion and Corrosion Testing (Withdrawn 2010)³
- G16 Guide for Applying Statistics to Analysis of Corrosion Data
- G46 Guide for Examination and Evaluation of Pitting Corrosion
- G69 Test Method for Measurement of Corrosion Potentials of Aluminum Alloys

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 *absorber*—a boron-based neutron-absorbing material system.

¹ This guide is under the jurisdiction of ASTM Committee C26 on Nuclear Fuel Cycle and is the direct responsibility of Subcommittee C26.03 on Neutron Absorber Materials Specifications.

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² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

³ The last approved version of this historical standard is referenced on www.astm.org.

3.1.2 *confirmation tests*—tests that may be necessary to confirm the continued presence and integrity of the neutron absorber.

3.1.3 *high-density storage*—the close-packing of spent fuel to the extent that absorbers are required for neutron flux reduction to assure adequate sub-criticality margin.

3.1.4 *irradiation (flux)*—the incidence of neutron and gamma radiation from spent-fuel assemblies on materials in a water-filled spent fuel pool.

3.1.5 *neutron attenuation test*—for neutron absorber materials, a process in which a material is placed in a thermal neutron beam, and the number of neutrons transmitted through the material in a specified period of time is counted. The neutron count can be converted to areal density by performing the same test on a series of appropriate calibration standards and comparing the results. This definition is applicable to in-situ testing of neutron absorber materials or the testing of surveillance coupons.⁴

3.1.6 *neutron blackness test*—a qualitative test using a neutron source for locating any unshielded areas within an absorber.

3.1.7 *sample*—one or more specimens of the absorber selected by some predetermined sampling process.

3.1.8 *service life*—the period of time for which properties of the absorber are expected to remain in compliance within the design specifications.

3.1.9 *specimen*—an individual full-size piece of the absorber or any portion thereof selected and prepared as necessary for test purposes.

4. Significance and Use

4.1 The storage of nuclear fuel in high-density storage racks is dependent upon the presence and performance of an absorber between the stored fuel assemblies to ensure that the reactivity of the storage configuration does not exceed the K-effective allowed by applicable regulations. A confirmation test may be required to verify the presence and performance of the absorber within the racks. When the absorbers are not visible or accessible for inspection (such as being fixed within the walls of the structure surrounding the storage position in the rack) a surveillance test program may be conducted on representative specimens of the absorber that are accessible and exposed to the same environmental factors as those in the rack.

4.2 This guide provides guidance for establishing and conducting a surveillance program for monitoring the ongoing performance of the absorbers.

5. Characteristics to be Monitored

5.1 The primary function of the absorber is to provide sufficient total-removal cross section for thermal neutrons throughout the relatively high (neutron) flux region between the active zones of adjacent fuel assemblies. The most important characteristic to be monitored is the ability of the absorber

to continuously and effectively remove thermal neutrons. This characteristic may vary over time after exposure to the heat, radiation, water chemistry, and mechanical forces experienced by the racks from the storage of nuclear fuel.

5.1.1 The metal-based absorbers may be monitored for verification of adequate neutron absorbing capability by periodic neutron attenuation tests or neutron blackness tests, or both. They may also be monitored for radiation damage, corrosion effects or other types of deterioration that reduce the physical integrity or neutron performance of the absorbers below the predetermined limits for the design service life of the racks (see 8.3).

5.1.2 The polymer-based absorbers may require augmented monitoring over and above periodic specimen surveillance by periodic neutron attenuation tests or neutron blackness tests, or both.⁵ The monitoring may also include consideration of radiation damage or other types of deterioration that may reduce the physical integrity or neutron performance of the absorber below the predetermined limits for the design service life of the racks (see 8.3).

6. Surveillance Specimens

6.1 Wherever possible, the design of surveillance specimens shall be in accordance with the requirements of ASTM test methods for the specific properties of interest to be measured. The size and configuration of certain specimens may be representative of those contained in the racks (see 6.1.2) in every respect possible, and yet be retrievable from the representative exposure areas of the racks at periodic intervals. The size and configuration of the specimens shall be appropriate for monitoring those characteristics where changes may be anticipated such as corrosion effects, radiation shrinkage, or degradation of the physical properties. It is recommended that archive (benchmark) specimens be retained for the duration of the surveillance program. In all cases, the exposed and nonexposed (archive) specimens shall be of the same size and shape. The pre-characterization of specimens shall be performed with respect to the important parameters.

6.1.1 The specimens for the metal-based absorbers shall be suitable for neutron attenuation testing, weight gain (due to corrosion), and dimensional changes due to pitting, cracking or blistering.

6.1.2 The specimens for the polymer-based absorber shall be suitable for neutron attenuation testing, and the specimens shall be large enough to obtain practical radiation shrinkage/cracking and other test data.

7. Measurement Methods and Frequencies

7.1 The selection and qualification of measurement methods shall be in accordance with Guide C1068 and in compliance with all regulatory requirements and with the recommendations of 6.1.1 and 6.2 of Specification C992 as deemed appropriate. The frequency of measurements shall be determined based on the previous site measurements, experience at other similar

⁴ Pierce, T.B., "Some uses of neutrons from non-reactor sources for the examination of metals and allied materials," IAEA-SM-159/17, pp. 49–61.

⁵ Lindquist, K. et al., "Radiation induced changes in the physical properties of Boraflex™ a neutron absorber material for nuclear applications," J. Nuclear Materials, 217 (1994), 223–225.