INTERNATIONAL

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Standard Guide for Establishing Surveillance Test Program for Boron-based Neutron Absorbing Material Systems for Use in Nuclear Fuel Storage Racks in Pool Environment[1]

This standard is issued under the fixed designation C1187; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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 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 functionality and integrity of the 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 fuel. There are several different techniques for surveillance testing of boron-based neutron absorbing materials. This guide focuses on coupon monitoring and in-situ testing.

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

1.3 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C859 Terminology Relating to Nuclear Materials
C992 Specification for Boron-based Neutron Absorbing Material Systems for Use in Nuclear Fuel Storage Racks in Pool Environment
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/E8M Test Methods for Tension Testing of Metallic Materials
E45 Test Methods for Determining the Inclusion Content of Steel
E74 Practices for Calibration and Verification for Force-Measuring Instruments
E290 Test Methods for Bend Testing of Material for Ductility

[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.

E2971 Test Method for Determination of Effective Boron-10 Areal Density in Aluminum Neutron Absorbers using Neutron Attenuation Measurements
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:*

3.1.1 For definitions of terms used in this guide, refer to Terminology C859.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *absorber, n*—a boron-based neutron-absorbing material system.

3.2.2 *areal density, n—for neutron absorber materials with flat parallel surfaces*, the mass of boron-10 per unit area of a sheet, which is equivalent to the mass of boron-10 per unit volume ~~of boron-10~~ in the material multiplied by the thickness of the material in which that isotope is ~~contained~~contained.

3.2.3 *confirmation tests, n*—tests that may be necessary to confirm the continued functionality and integrity of the neutron absorber.

3.2.4 *degradation, n*—a change in a material property that lessens the original design functionality.

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

3.2.6 *in-situ neutron attenuation test, n*—a qualitative or quantitative test using a neutron source for determining neutron absorbing functionalities.

3.2.7 *in-situ test, n*—remote characterization of absorber material in the storage racks.

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

3.2.9 *neutron attenuation test, n*—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]

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

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

3.2.12 *specimen, n*—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 functionality and integrity 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 functionality and integrity of the absorber within the racks. If establishing a surveillance program for newly installed or existing absorber material in fuel racks, the following methods are suggested: (*a*) coupon monitoring program (if coupons are available), (*b*) in-situ neutron attenuation test, and (*c*) other applicable in-situ tests such as visual inspection or drag test.

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

5. Characteristics to Be Monitored

5.1 The primary function of the absorber is to provide sufficient absorption 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 or natural phenomena, or both.

[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.~~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.

5.1.1 Absorbers should be monitored for verification of adequate neutron absorbing functionality by periodic neutron attenuation tests of removable surveillance specimens or in-situ neutron attenuation tests, or both.

5.1.2 Absorbers characterization should include consideration of radiation damage or other types of deterioration that may reduce the physical integrity or functionality 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 should be in accordance with the requirements of ASTM standards for the specific properties of interest to be measured. The size and configuration of certain specimens should be representative of the absorbers contained in the racks (see ~~6.1.2~~6.1.1 and 6.1.2) in every respect possible, and the conditions to which the specimens are exposed should be representative of the environmental factors existing in the rack. The specimens should be configured such that they are retrievable from the representative exposure areas of the racks at periodic intervals. The size and configuration of the specimens should 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 non-exposed (archive) specimens shall be of the same size and shape. The pre-characterization of specimens shall be performed with respect to the parameters of importance to functionality.

6.1.1 The specimens for the metal-based absorbers shall be suitable for neutron attenuation testing, weight change (due to degradation), and changes including pitting, cracking, and 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 appropriate. The frequency of measurements shall be determined based on the previous site measurements, experience at other similar sites, and from published data on the particular absorber, as available.[5] Acceptance criteria shall be established for key characteristics that are selected prior to implementing a surveillance program. Acceptance criteria are established by the designer for approval by the owner and regulating authorities.

7.1.1 *Neutron Absorber Performance*—The quantitative measurement of the performance of an absorber requires a neutron source and sensitive neutron detection devices. The test specimen of neutron absorber material shall meet the required absorber areal density as specified in the design specification such as the Safety Analysis Report (SAR). Measurement error and uncertainty shall be considered. Aluminum-based absorber specimens should be tested in accordance with Test Method E2971.

7.1.2 *Physical Characteristics*—Physical characteristics shall be measured in accordance with generally accepted practices in the nuclear industry. The test specimen shall meet the minimum required physical characteristics as specified in the design specification such as the Safety Analysis Report. Measurement error and uncertainty shall be considered. Some physical characteristics may be determined by in-situ tests such as visual inspection.

7.1.3 *Mechanical Characteristics*—Mechanical tests shall be performed commensurate with the functionality expected of the absorber. Consideration shall be given to the expected service life of the neutron absorber; normal, off normal and accident conditions; and whether the absorber performs in a load bearing or non-load bearing role. The mechanical requirements of the absorber should be reflected in the design specification such as the SAR. When required, mechanical characteristics of the metal-based absorber shall be assessed in accordance with procedures such as Terminology E6, Test Methods E8/E8M ~~and~~ , E45, ~~Practice E74~~E290, and ~~Test Method~~ Practice ~~E290~~E74. When required, mechanical characteristics of the polymer-based absorber should be measured in accordance with procedures such as Test Methods D412, D430, D518, D813, D1415, D2240, and Practices D3183 and D4483. Some mechanical characteristics may be determined by in-situ tests.

7.1.4 *Corrosion Characteristics*—Coupons should be examined for corrosion; the rate and type of corrosion will be evaluated for the effect on the ability of the neutron absorber to perform its design functions for the intended service life. The corrosion performance requirements of the absorber should be reflected in the design specification such as the SAR. Corrosion characteristics of the metal-based absorber shall be assessed in accordance with procedures such as Practice G1, Guides G4, G16, and G46, Terminology G15, and Test Method G69. Corrosion characteristics cannot be determined by in-situ tests.

8. Records and Reporting

8.1 Collection, storage, and control of records required by this guide shall be in accordance with the requirements of the relevant regulations and appropriate specifications.

8.2 A report is required. It shall include the following surveillance program description and other information, and provide both SI units and conventional units as applicable:

[5] Jun, Insoo and Myung Jae Song. "Nuclear Analysis for the Boraflex Used in a Typical Spent Fuel Storage Assembly." *Nuc. Tech* Vol 109 (March 1995): 357–365.