Designation: C 1187 – 07

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

This standard is issued under the fixed designation C 1187; 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 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]

C 992 Specification for Boron-Based Neutron Absorbing Material Systems for Use in Nuclear Spent Fuel Storage Racks
C 1068 Guide for Qualification of Measurement Methods by a Laboratory Within the Nuclear Industry
D 412 Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension
D 430 Test Methods for Rubber Deterioration—Dynamic Fatigue
D 518 Test Method for Rubber Deterioration—Surface Cracking
D 813 Test Method for Rubber Deterioration—Crack Growth
D 1415 Test Method for Rubber Property—International Hardness
D 2240 Test Method for Rubber Property—Durometer Hardness
D 3183 Practice for Rubber—Preparation of Product Pieces for Test Purposes from Products
D 4483 Practice for Evaluating Precision for Test Method Standards in the Rubber and Carbon Black Manufacturing Industries
E 6 Terminology Relating to Methods of Mechanical Testing
E 8 Test Methods for Tension Testing of Metallic Materials
E 23 Test Methods for Notched Bar Impact Testing of Metallic Materials
E 74 Practice of Calibration of Force-Measuring Instruments for Verifying the Force Indication of Testing Machines
E 290 Test Methods for Bend Testing of Material for Ductility
G 1 Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens
G 4 Guide for Conducting Corrosion Tests in Field Applications
G 15 Terminology Relating to Corrosion and Corrosion Testing
G 16 Guide for Applying Statistics to Analysis of Corrosion Data
G 46 Guide for Examination and Evaluation of Pitting Corrosion
G 69 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.

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

[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.

Current edition approved July 1, 2007. Published August 2007. Originally approved in 1991. Last previous edition approved in 1999 as C 1187 – 91 (1999).

[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.

3.1.3 *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.[3]

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.[4] 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 C 1068 and in compliance with all regulatory requirements and with the recommendations of 6.1.1 and 6.2 of Specification C 992 as deemed 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, or any

[3] 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.

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

of the three.[5] Acceptance criteria shall be established for each of the measurement methods selected prior to implementing a surveillance program.

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 or exceed the required absorber areal density as specified in the design specification or Safety Analysis Report (SAR). Measurement error and uncertainty shall be considered.

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 or Safety Analysis Report. Measurement error and uncertainty shall be considered.

7.1.3 *Mechanical Characteristics*—Mechanical tests shall be performed commensurate with the duty expected of the absorber. Consideration shall be given to the expected performance 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 and SAR. When required, mechanical characteristics of the metal-based absorber shall be assessed in accordance with procedures such as Definitions E 6, Test Methods E 8 and E 45, Practice E 74 and Test Method E 290. When required, mechanical characteristics of the polymer-based absorber shall be measured in accordance with procedures such as Test Methods D 412, D 430, D 518, D 813, D 1415, D 2240, Practices D 3183 and D 4483.

7.1.4 *Corrosion Characteristics*—Coupons shall 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 lifetime. The corrosion performance requirements of the absorber should be reflected in the design specification and SAR. Corrosion characteristics of the metal-based absorber shall be assessed in accordance with procedures such as Practice G 1, Guide G 4, Definitions G 15, Practices G 16, G 46 and G 69.

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:

8.2.1 *Program*—The location and duration of the surveillance specimens with respect to the proximity, burn-up and age of the spent fuel assemblies, and any other pertinent environmental parameters shall be provided.

8.2.2 *Sample Description*—A description of surveillance samples, including such information as configuration, fabrication history, material certifications, chemical analysis, physical analysis, and any other pertinent data shall be provided.

8.2.3 *Test Schedule*—A test schedule shall be provided showing the exposure period and test locations for each of the surveillance specimens so the accumulated exposure time and total radiation doses for each specimen are known and controlled in accordance with the surveillance program.

8.2.4 *Test Results*—The test results of all measurements taken shall be recorded and compared against the original baseline and predicted data.

8.2.5 *Test Conclusions*—An objective assessment of the test results shall be given and a statement made to the effect that the performance of the absorbers are or are not expected to meet the stated performance criteria for the design service-life period (see 3.1.1.6 and section 4.1.1 of Specification C 992).

8.3 *Additional Comments*—Any additional information, such as test or calculation uncertainties, time-history of pool water chemistry and any known excursions from the baseline conditions, that would be pertinent to the purpose of the surveillance testing shall be reported.

9. Keywords

9.1 boron-based neutron-absorbing material systems; high-density storage; irradiation; metal-based; neutron attenuation; neutron blackness; neutron flux; polymer-based; reactivity; service life; surveillance.

[5] IHSOO, "Nuclear analysis for the Boraflex used in a typical spent fuel storage assembly," Nuc. Tech, Vol 109, March 1995, pp. 357–365.