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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 Racks[1]

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1. Scope

1.1 This guide provides advice for establishing a surveillance test program to monitor the performance of boron-based neutron absorbing material systems (absorbers) in nuclear spent fuel storage racks. The recommended 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:*

C 859 Terminology Relating to Nuclear Materials[2]

C 992 Specification for Boron-Based Neutron Absorbing Material Systems for Use in Nuclear Spent Fuel Storage Racks[2]

C 1068 Guide for Qualification of Measurement Methods by a Laboratory Within the Nuclear Industry[2]

D 412 Test Methods for Vulcanized Rubber and Thermoplastic Rubbers and Thermoplastic Elastomers—Tension[3]

D 430 Test Methods for Rubber Deterioration—Dynamic Fatigue[3]

D 518 Test Method for Rubber Deterioration—Surface Cracking[3]

D 813 Test Method for Rubber Deterioration—Crack Growth[3]

D 1415 Test Method for Rubber Property—International Hardness[3]

D 2240 Test Method for Rubber Property—Durometer Hardness[3]

D 3183 Practice for Rubber—Preparation of Pieces for Test Purposes from Products[3]

D 4483 Practice for Determining Precision for Test Method Standards in the Rubber and Carbon Black Industries[3]

E 6 Terminology Relating to Methods of Mechanical Testing[4]

E 8 Test Methods for Tension Testing of Metallic Materials[4]

E 23 Test Methods for Notched Bar Impact Testing of Metallic Materials[4]

E 74 Practice for Calibration of Force Measuring Instruments for Verifying the Force Indication of Testing Machines[4]

E 290 Test Method for Semi-Guided Bend Test for Ductility of Metallic Materials[4]

E 1027 Practice for Exposure of Polymeric Materials to Ionizing Radiation[5]

G 1 Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens[6]

G 4 Method for Conducting Corrosion Coupon Tests in Plant Equipment[6]

G 15 Terminology Relating to Corrosion and Corrosion Testing[6]

G 16 Guide for Applying Statistics to Analysis of Corrosion Data[6]

G 46 Practice for Examination and Evaluation of Pitting Corrosion[6]

G 69 Practice for Measurement of Corrosion Potentials of Aluminum Alloys[6]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

Terms shall be defined in accordance with Terminology C 859 except as defined as follows:

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

3.1.1.2 *high-density storage*—the close-packing of spent fuel to the extent that absorbers are required for neutron flux reduction.

3.1.1.3 *irradiation*—the neutron, beta and gamma fluxes,

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[2] *Annual Book of ASTM Standards*, Vol 12.01.

[3] *Annual Book of ASTM Standards*, Vol 09.01.

[4] *Annual Book of ASTM Standards*, Vol 03.01.

[5] *Annual Book of ASTM Standards*, Vol 12.02

[6] *Annual Book of ASTM Standards*, Vol 03.02.

from spent-fuel assemblies in a water-filled spent fuel pool.

3.1.1.4 *neutron attenuation*—that fraction of the neutron flux striking the surface of the absorber that is not transmitted through it. This is a quantitative characteristic.

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

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

3.1.1.7 *service life*—the period of time for which properties of the absorber are expected to remain in compliance with the contract requirements.

3.1.1.8 *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 spent 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. The Nuclear Regulatory Commission has required in certain instances the verification of 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 advice 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 high (neutron) flux region between the active zones of two 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 spent 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 (that is, losses) 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. 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.

6.1.1 The specimens for the metal-based absorbers shall be suitable for neutron attenuation testing, neutron blackness testing, or both, and any other tests as deemed necessary.

6.1.2 The specimens for the polymer-based absorber shall be suitable for neutron attenuation testing, neutron blackness testing, or both, and large enough to obtain practical radiation shrinkage data and any other test data as deemed necessary (see Practice E 1027).

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

7.1.1 *Neutron Absorbing Performance*—The quantitative measurement of the performance of an absorber requires a neutron source and sensitive neutron detection devices. For an example of an acceptable procedure for performing such a test, see Neutron Attenuation Testing.[7]

7.1.2 *Physical Characteristics*—When required, physical characteristics shall be measured in accordance with generally accepted practices in the nuclear industry.

7.1.3 *Mechanical Characteristics*—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] Neutron Attenuation Testing Procedure, available from Phoenix Memorial Laboratory, Attn: Manager, Nuclear Reactor Laboratory, 2301 Bonisteel Blvd., University of Michigan, Ann Arbor, MI 48109-2100.

7.1.4 *Corrosion Characteristics*—When required, 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 If 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 perimeters shall be provided.

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

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

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.