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StandardSpecification 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 specification defines criteria for boron-based neutron absorbing material systems used in racks in a pool environment for storage of nuclear light water reactor (LWR) spent-fuel assemblies or disassembled components to maintain sub-criticality in the storage rack system.

1.2 Boron-based neutron absorbing material systems normally consist of metallic boron or a chemical compound containing boron (for example, boron carbide, B_4C) supported by a matrix of aluminum, steel, or other materials.

1.3 In a boron-based absorber, neutron absorption occurs primarily by the boron-10 isotope that is present in natural boron to the extent of 18.3 ± 0.2 % by weight (depending upon the geological origin of the boron). Boron, enriched in boron-10 could also be used.

1.4 The materials systems described herein shall be functional – that is always be capable to maintain a B10 areal density such that subcriticality Keff <0.95 or Keff <0.98 or Keff < 1.0 depending on the design specification for the service life in the operating environment of a nuclear spent fuel pool.

1.5 A number of acceptable boron-based absorbing materials combinations are currently available while others are being developed for use in the future. This specification defines criteria essential and applicable to all materials combinations and identifies parameters a buyer should specify to satisfy a unique or particular requirement.

1.6 The scope of this specification does not comprehensively cover all provisions for preventing criticality accidents or requirements for health and safety. Observance of this specification does not relieve the user of the obligation to conform to all applicable international, national, and local regulations.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A240/A240M Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications

B209 Specification for Aluminum and Aluminum-Alloy Sheet and Plate

C750 Specification for Nuclear-Grade Boron Carbide Powder

C859 Terminology Relating to Nuclear Materials

C1187 Guide for Establishing Surveillance Test Program for Boron-Based Neutron Absorbing Material Systems for Use in Nuclear Spent Fuel Storage Racks

E105 Practice for Probability Sampling of Materials

ASTM Dictionary of Engineering Science and Technology

2.2 *ANSI Standards:*[3]

ANSI 45.2.2 Packaging, Shipping, Receiving, Storage and Handling of Items for Nuclear Power Plants

ANSI-ASME NQA-1 Quality Assurance Requirements for Nuclear Facility Application

2.3 *U. S. Government Documents:*[4]

10CFR50 Title 10, CFR, Energy Part 50 — Licensing of Production and Utilization Facilities

10CFR72 Title 10, CFR, Energy Part 72 — Licensing Requirements for the Storage of Spent Fuel in an Independent Spent Fuel Storage Installation (ISFSI)

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 Terms shall be defined in accordance with Terminology C859 or the ASTM Dictionary of Engineering Science and Technology, except as defined as follows:

3.1.2 *accelerated testing*—a procedure for investigating the potential for long-term changes in physical properties or

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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] Available from the American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

[4] Available from Superintendent of Documents, U. S. Government Printing Office, Washington, DC 20402.

chemical composition of a material important to safety, caused by a system operating parameter such as temperature, chemical environment or radiation.

3.1.2.1 *Discussion*—The procedure uses a value of the identified parameter that is outside the normal bound of the operating parameter being investigated, in order to (*1*) increase the rate of degradation, if any, (*2*) identify the operating limit for acceptable limit of the parameter, and (*3*) to provide information that might assist in interpreting the degradation mechanism(s) involved. In this manner, the long-term behavior of a material may be simulated in an appreciably shorter period of time.

3.1.3 *areal density*—the boron-10 per unit area of a sheet, which is equivalent to the mass per unit volume of boron-10 in the material multiplied by the thickness of the material in which that isotope is contained.

3.1.4 *buyer*—the organization issuing the purchase order.

3.1.5 *individual piece*—a discrete section of neutron absorber material whose individual dimensions conform to those in the purchase specification.

3.1.6 *irradiation*—the incidence of neutron, gamma, and beta radiation from spent fuel assemblies on materials in a water-filled spent fuel pool.

3.1.7 *production batch*—a group of neutron-absorbing material pieces produced in a continuous production period, all of which can be shown to have the same chemical composition, physical, and nuclear properties within specification limits.

3.1.8 *seller*—the neutron absorbing system manufacturer.

3.1.9 *service life*—the period of time for which properties of the neutron-absorbing material system are expected to remain in compliance with the contract requirements which relate to chemical and physical integrity.

3.1.10 *supplier*—any outside source of raw materials and services used by the seller.

4. Ordering Information

4.1 The buyer should specify a material for which there is documented evidence that the neutron absorbing material system is capable of acceptable performance in the following environmental conditions to which the material is expected to be exposed:

4.1.1 Total service life of the neutron absorbing material system,

4.1.2 Maximum integrated irradiation over the total service life of the neutron absorbing material system, and

4.1.3 Chemical and thermal environment of the water in the spent fuel pool in which the neutron absorbing material system will be located.

4.2 The buyer shall specify the following physical and chemical properties of the neutron absorbing material system; this may include archive or in-service surveillance coupons:

4.2.1 Total quantity of individual pieces required,

4.2.2 Physical dimensions of each individual piece required, and may also include physical form limitations including flatness, camber, bow, etc.,

4.2.3 Boron-10 isotopic content of the neutron absorbing material system expressed in terms of grams of isotopic B-10 per cm^2 of surface area. Alternatively, the boron-10 content may be specified by material density, the weight percent boron, minimum thickness, and the minimum acceptable weight fraction of boron-10 in the boron.

4.2.4 Applicable tolerances for each dimension or property, including minimum boron-10 areal density.

4.2.5 Material specifications for the components of the neutron absorbing material system shall be in accordance with Specifications A240/A240M, B209, and C750, if applicable.

4.3 In addition to the properties of 4.2, the buyer shall specify the following system properties as required by the specific spent fuel storage rack design:

4.3.1 Structural properties for the neutron absorbing material system, if required, and

4.3.2 Limitations on gas evolution, product cleanliness, or other physical characteristics, if applicable.

5. Material System Properties

5.1 The boron-10 shall be uniformly distributed throughout the neutron absorbing material system as defined in 7.3 and 8.1.4.

5.2 The neutron absorbing material system may contain, in addition to the boron or boron compound, any matrix materials necessary to maintain that boron in the state of specified uniformity and areal density throughout the stipulated service life of the spent fuel storage system.

5.2.1 The seller shall provide to the buyer a chemical analysis of the neutron absorbing material system, so that the buyer may determine the compatibility of the neutron absorbing material with the spent fuel storage rack and the pool environment.

5.3 The seller shall provide the buyer with the elemental and boron isotopic composition of the neutron absorbing material system and the particle size distribution when necessary of the boron compound so that the buyer may determine the neutron attenuating and absorbing properties of the material and its suitability for the buyer's application.

5.4 The loss of boron through any degradation mechanisms shall not lower the areal density below the allowable limits within the stated service life (see Section 6.1.1).

5.5 It is recommended that in-service surveillance tests be performed to monitor the areal density (see Guide C1187). It is further recommended that these tests determine both physical and performance characteristics. The physical tests should determine at least the size, weight, density, and surface appearances, including any surface blistering, delamination, or pitting. The performance tests should determine at least the neutron attenuation capabilities and mechanical strength, if applicable. The test samples should be positioned to maximize the irradiation doses the samples will receive during each exposure period. The before and after exposure test results should be compared to determine any unfavorable changes in the physical or performance characteristics.