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Standard Specification for Boron-Based Neutron Absorbing Material Systems for Use in Nuclear Fuel Storage Racks in a Pool Environment[1]

This standard is issued under the fixed designation C992; 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 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 boron-10 areal density such that subcriticality is maintained depending on the design specification for the service life in the operating environment of a nuclear spent fuel pool.

1.5 Observance of this specification does not relieve the user of the obligation to conform to all applicable international, national, and local regulations.

1.6 *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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C859 Terminology Relating to Nuclear Materials

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

E105 Practice for Probability Sampling of Materials

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

ASTM Dictionary of Engineering Science and Technology

2.2 *ANSI and ASME Standards:*[3]

ANSI N45.2.2 Packaging, Shipping, Receiving, Storage and Handling of Items for Nuclear Power Plants

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 Terms shall be defined in accordance with Terminology C859 or the ASTM Dictionary of Engineering Science and Technology

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *accelerated testing*—a procedure for investigating the potential for long-term changes in physical properties or chemical composition of a material important to safety, caused by a system operating parameter such as temperature, chemical environment or radiation.

3.2.1.1 *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

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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.

mechanism(s) involved. In this manner, the long-term behavior of a material may be simulated in an appreciably shorter period of time.

3.2.2 *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.

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

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

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

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

3.2.7 *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.

3.2.8 *seller*—the neutron absorbing system manufacturer.

3.2.9 *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 material functionality.

3.2.10 *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 Environment of the fuel pool in which the neutron absorbing material system will be located, including consideration of normal operation and effects of anticipated operational occurrences.

4.2 The buyer shall specify the following material properties and applicable tolerances 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 Material for the components of the neutron absorbing material system shall be in accordance with applicable specifications or standards.

4.2.5 Mechanical properties of the neutron absorbing material system for structural requirements, as required.

4.2.6 Acceptance criteria for 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 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 boron-10 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 Material system's neutron absorbing capability shall not be reduced below the allowable limit within the stated service life (see 6.1.1) including geometric changes, loss of boron, or other degradation.

5.5 In-service surveillance tests shall be performed to monitor the material system properties (for example, see Guide C1187).

6. Test Documentation

6.1 The seller shall provide to the buyer documentation of tests performed to characterize the neutron absorbing material system performance and mechanical properties.

6.1.1 When appropriate, accelerated test may be performed to demonstrate compliance to 5.4. The test reports shall include both a description of procedures and a review of results.

6.2 The buyer shall determine the suitability of the neutron absorbing material system for the buyer's application on the basis of evidence offered by the seller, which may include accelerated test documentation, and by additional testing and evaluation performed by the buyer.

7. Sampling

7.1 Sampling plans to meet acceptance criteria and inspection and measurement procedures that describe the method of compliance with this specification shall be established by the seller and submitted to the buyer for approval prior to manufacture of the required product. The degree of sampling shall be specified by the purchase order. Practice E105 is referenced as a guide.

7.2 Each sample taken shall be sufficient for quality control tests, acceptance tests, referee tests, and archive samples as necessary or desired by the buyer.

7.3 To show uniformity of the boron-10, the seller shall demonstrate that the sampling for boron-10 areal density is adequate for establishing that the minimum boron-10 areal density is achieved throughout the product with a probability and confidence approved by the buyer.

7.4 Archive samples shall be retained by the seller for a period of time specified by the buyer and delivered to the buyer upon request.

8. Inspection

8.1 Inspection of the neutron absorbing material shall be by production batch and by individual piece.

8.1.1 Evaluation of chemical composition, density, boron-10 areal density, and uniformity may be made on a production batch basis.

8.1.2 Inspection of dimensions and physical form shall be made by individual piece.

8.1.3 Inspection of the neutron absorbing material for defects and cleanliness (for example, any oils or foreign materials) shall be performed by individual piece.

8.1.4 The boron-10 quantity and uniformity shall be determined. Determination may be performed by a neutron attenuation measurement per Test Method E2971 or by a combination of isotopic analysis, chemical analysis, and physical measurements. The validity of other techniques must be demonstrated.

9. Rejection

9.1 Items that fail to conform to the requirements of the specification may be rejected by the buyer. The seller may petition to the buyer to waive the specifications for specific out-of-specification items. Decision to grant such waiver belongs to the buyer. The seller may also effect any remedy to bring rejected items into specification providing he can demonstrate to the buyer that such remedy does not impair the function or preclude the certification of the neutron absorbing material system.

10. Certification

10.1 When specified in the purchase order or contract, the seller shall prepare a certification that the neutron absorbing material system was manufactured, sampled, tested, and inspected in accordance with the specifications and has been found to meet the requirements. When specifically required, testing results of the material shall accompany the certification. Each certification furnished shall be signed by an authorized agent of the seller.

11. Marking, Packaging, and Shipping

11.1 For marking, packaging, and shipping, ANSI N45.2.2 is referenced as a guide. Each individual piece of neutron absorbing material system shall be marked on one face in a location agreed upon by the buyer and seller with a serial identification traceable to the test analysis, production batch, and certification. The characters of the markings shall be of such size as to be clearly legible. The markings shall be sufficiently durable to withstand normal handling. The buyer shall approve the method of marking.

11.2 The neutron-absorbing material shall be packaged for shipment in a suitable manner to assure that the material will normally arrive in an undamaged condition.

11.2.1 The buyer shall indicate to the seller unusual conditions of handling or storage and specify additional protective packaging as necessary.

11.2.2 Each package of neutron-absorbing material shall be identified as to buyer, seller, contents, and quantity as a minimum and any other information specified by the seller.

11.3 Method of shipping shall be specified by the buyer. The selected method shall be suitable to protect the neutron absorbing material system from direct weather exposure and mechanical damage.

12. Quality Assurance

12.1 Quality assurance requirements shall be specified in the purchase order. 10CFR50, Appendix B, 10CFR72, and ANSI-ASME NQA-1 are referenced as guides.

13. Keywords

13.1 boron; spent fuel; storage rack