



Standard Specification for Boron-Based Neutron Absorbing Material Systems for Use in Nuclear Spent Fuel Storage Racks¹

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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 $K_{eff} < 0.95$ or $K_{eff} < 0.98$ or $K_{eff} < 1.0$ 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.

¹ This specification 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. 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

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 cm² 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.

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 accelerated test documentation and other evidence offered by the seller 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 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, 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 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

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