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Standard Practice for Qualification and Acceptance of Boron Based Metallic Neutron Absorbers for Nuclear Criticality Control for Dry Cask Storage Systems and Transportation Packaging¹

This standard is issued under the fixed designation C1671; 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 practice provides procedures for qualification and acceptance of neutron absorber materials used to provide criticality control by absorbing thermal neutrons in systems designed for nuclear fuel storage, transportation, or both.

1.2 This practice is limited to neutron absorber materials consisting of metal alloys, metal matrix composites (MMCs), and cermets, clad or unclad, containing the neutron absorber boron-10 (^{10}B).

1.3 *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

[B557 Test Methods for Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products](#)

[B557M Test Methods for Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products \(Metric\)](#)

[C791 Test Methods for Chemical, Mass Spectrometric, and Spectrochemical Analysis of Nuclear-Grade Boron Carbide](#)

[E8 Test Methods for Tension Testing of Metallic Materials](#)

[E21 Test Methods for Elevated Temperature Tension Tests of Metallic Materials](#)

[E456 Terminology Relating to Quality and Statistics](#)

[E1225 Test Method for Thermal Conductivity of Solids Using the Guarded-Comparative-Longitudinal Heat Flow Technique](#)

[E1461 Test Method for Thermal Diffusivity by the Flash Method](#)

3. Terminology

3.1 *Definitions:*

3.1.1 *acceptance test, n*—for a neutron absorber material, quality control, tests, and inspections conducted to determine whether a specific production lot meets selected specified material properties, characteristics, or both, so that the lot can be accepted.

3.1.2 *areal density, n*—for neutron absorber materials with flat parallel surfaces, the density of the neutron absorber times the thickness of the material (g/cm^2).

3.1.3 *durability, n*—the ability of neutron absorber materials to withstand service conditions without physical changes that would render them unable to perform their design functions.

3.1.4 *lot, n*—a quantity of a product or material accumulated under conditions that are considered uniform for sampling purposes. **E456**

3.1.5 *moderator, n*—a material used to reduce neutron energy by scattering without appreciable capture.

3.1.6 *neutron absorber, n*—a nuclide that has a large thermal neutron absorption cross section (also known as a neutron poison).

3.1.7 *neutron-absorber material, n*—a compound, alloy, composite or other material that contains a neutron absorber.

3.1.8 *neutron attenuation test, n*—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.

3.1.9 *neutron cross section, [barn], n*—a measure of the probability that a neutron will interact with a nucleus in the absorbing medium and is a function of the neutron energy.

3.1.10 *open porosity, n*—the volume fraction of all pores, voids, and channels within a solid mass that are interconnected

¹ This practice 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 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.

with each other and communicate with the external surface, and thus are measurable by gas or liquid penetration. **C242, C21**

3.1.11 *packaging, n—in transport of radioactive material*, the assembly of components necessary to enclose the radioactive contents completely.³

3.1.12 *probability sampling, n*—a sample selection procedure in which the sampling units are selected by a chance process such that, at each step of the selection, a specified probability of selection can be attached to each sampling unit available for selection. **E456**

3.1.13 *qualification, n—for neutron absorber materials*, the process of evaluating, testing, or both, a material produced by a specific manufacturing process to demonstrate uniformity and durability for a specific application.

3.1.14 *systematic sampling, n*—a sample selection procedure in which every k th element is selected from the universe or population, for example, $u, u + k, u + 2k, u + 3k$, etc., where u is in the interval 1 to k . **E456**

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *Designer, n*—the organization responsible for the design or the license holder for the dry cask storage system or transport packaging. The designer is usually the purchaser of the neutron absorber material, either directly or indirectly (through a fabrication subcontractor).

4. Significance and Use

4.1 For criticality control of nuclear fuel in dry storage and transportation, the most commonly used neutron absorber materials are borated stainless steel alloys, borated aluminum alloys, and boron carbide aluminum alloy composites. The boron used in these neutron absorber materials may be natural or enriched in the nuclide ^{10}B . The boron is usually incorporated either as an intermetallic phase (for example, AlB_2 , TiB_2 , CrB_2 , etc.) in an aluminum alloy or stainless steel, or as a stable chemical compound particulate such as boron carbide (B_4C), typically in an aluminum MMC or cermet.

4.2 While other neutron absorbers continue to be investigated, ^{10}B has been most widely used in these applications, and it is the only thermal neutron absorber addressed in this standard.

4.3 In service, many neutron absorber materials are inaccessible and not amenable to a surveillance program. These neutron absorber materials are often expected to perform over an extended period.

4.4 Qualification and acceptance procedures demonstrate that the neutron absorber material has the necessary characteristics to perform its design functions during the service lifetime.

4.5 The criticality control function of neutron absorber materials in dry cask storage systems and transportation packagings is only significant in the presence of a moderator,

such as during loading of fuel under water, or water ingress resulting from hypothetical accident conditions.

4.6 The expected users of this standard include designers, neutron absorber material suppliers and purchasers, government agencies, consultants and utility owners. Typical use of the practice is to summarize practices which provide input for design specification, material qualification, and production acceptance. Adherence to this standard does not guarantee regulatory approval; a government regulatory authority may require different tests or additional tests, and may impose limits or restrictions on the use of a neutron absorber material.

5. Procedure

5.1 *Determination of Service Conditions and Design Requirements for the Neutron Absorber Material*—The designer shall specify the service conditions and design requirements, including environmental conditions, mechanical properties, and areal density or equivalent measure of neutron absorber content. Selection of environmental and service conditions that are important for neutron absorber material performance and qualification should take into consideration known failure modes and industry experience.

5.1.1 Environmental conditions to be considered include but are not limited to water chemistry, water temperature, paired dissimilar materials, hydrostatic pressure, duration of immersion, gamma and fast neutron flux, heat-up rate after draining, and maximum temperature.

5.1.2 For structural applications, specify the mechanical properties required by the structural analysis. For non-structural uses of the neutron absorber material, specify mechanical properties sufficient to assure material durability under the service conditions for which it is designed.

5.1.3 Specify other design properties, for example, thermal conductivity, surface finish, etc., as required for the application.

5.1.4 Product or feed material chemistry shall be specified.

5.2 *Neutron Absorber Material Qualification*—Qualification shall consist of three components: (1) verify durability for the intended service as defined in 5.2.5, (2) verify that the physical characteristics of components meet their design requirements defined in 5.2.6, and (3) verify that the uniformity of the ^{10}B distribution in the neutron absorber material is within acceptable bounds as specified by the designer as described in 5.2.6.

5.2.1 Qualification is needed:

5.2.1.1 When the neutron absorber material has not been previously qualified,

5.2.1.2 When a new supplier is producing a qualified neutron absorber material, or

5.2.1.3 When any key process or process control, as defined in 5.2.7, is altered for production of a qualified neutron absorber material.

5.2.2 The key processes and process controls for producing neutron absorber material for qualification should be the same as those to be used for commercial production. Differences shall be justified per 5.2.7.

5.2.3 If a previously qualified material is manufactured by a new supplier, the designer should do a review of key process and controls and perform qualification testing demonstrating

³“Regulations for the Safe Transport of Radioactive Material,” Safety Series Standards No. TS-R-1, International Atomic Energy Agency, Vienna, Austria.