Designation: E2971 – 14

Standard Test Method for Determination of Effective Boron-10 Areal Density in Aluminum Neutron Absorbers using Neutron Attenuation Measurements[1]

This standard is issued under the fixed designation E2971; 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 test method is intended for quantitative determination of effective boron-10 (^{10}B) areal density (mass per area of ^{10}B, usually measured in grams-$^{10}B/cm^2$) in aluminum neutron absorbers. The attenuation of a thermal neutron beam transmitted through an aluminum neutron absorber is compared to attenuation values for calibration standards allowing determination of the effective ^{10}B areal density. This test is typically performed in a laboratory setting. This method is valid only under the following conditions:

1.1.1 The absorber contains ^{10}B in an aluminum or aluminum alloy matrix.

1.1.2 The primary neutron absorber is ^{10}B.

1.1.3 The test specimen has uniform thickness.

1.1.4 The test specimen has a testing surface area at least twice that of the thermal neutron beam's surface cross-sectional area.

1.1.5 The calibration standards of uniform composition span the range of areal densities being measured.

1.1.6 The areal density is between 0.001 and 0.080 grams of ^{10}B per cm^2.

1.1.7 The thermalized neutron beam is derived from a fission reactor, sub-critical assembly, accelerator or neutron generator.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

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]

C1671 Practice for Qualification and Acceptance of Boron Based Metallic Neutron Absorbers for Nuclear Criticality Control for Dry Cask Storage Systems and Transportation Packaging

E1316 Terminology for Nondestructive Examinations

3. Terminology

3.1 For definitions of terms used in this test method, refer to Terminology E1316.

4. Summary of Test Method

4.1 In this test method, aluminum neutron absorbers are placed in a thermal neutron beam and the number of neutrons transmitted through the material in a known period of time is counted. The neutron count can be converted to ^{10}B areal density by performing the same test on a series of appropriate calibration standards and comparing the results.

4.2 This test method uses a beam of neutrons with the neutron energy spectrum thermalized by an appropriate moderator. Other methods such as neutron diffraction may be used to generate a thermal neutron beam.

4.3 A beam of thermal neutrons shall be derived from a fission reactor, sub-critical assembly, accelerator or neutron generator.

5. Significance and Use

5.1 The typical use of this test method is determination of ^{10}B areal density in aluminum neutron absorber materials used to control criticality in systems such as: spent nuclear fuel dry storage canisters, transfer/transport nuclear fuel containers, spent nuclear fuel pools, and fresh nuclear fuel transport containers.

[1] This test method is under the jurisdiction of ASTM Committee E07 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.05 on Radiology (Neutron) Method.

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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.

5.2 Areal density measurements are also used in the investigation of the uniformity in ^{10}B spatial distribution.

5.3 The expected users of this standard include designers, suppliers, neutron absorber users, testing labs, and consultants in the field of nuclear criticality analysis.

5.4 Another known method used to determine areal density of ^{10}B in aluminum neutron absorbers is an analytical chemical method as mentioned in Practice C1671. However, the analytical chemical method does not measure the "effective" ^{10}B areal density as measured by neutron attenuation.

6. Interferences

6.1 Counts not associated with attenuation by the sample shall be accounted for by measuring and incorporating background readings. Background reading will vary depending on the set up of the electronics of the system and the presence/absence of high energy photons.

6.2 Measured count rates approaching the background count rate may limit the abilities of a system to accurately measure highly attenuating samples.

6.3 Coincidence loss may occur in the ^{10}B detector(s) when the neutron count rate is too high.

7. Apparatus

7.1 The essential features required for areal density measurement are the following:

7.1.1 Source of thermal neutrons of an appropriate intensity to obtain the desired counting statistics in a reasonable time period while not saturating the detector. If the counting rate is too high, pulses can pile up, causing counts to be lost in what is called "coincidence loss." The detector time constant in most modern counting circuits is sufficiently small to accommodate up to 2×10^6 CPM. However, checks should be made to assure that the coincidence loss is not excessive.

7.1.2 A neutron beam intensity monitor for correction of neutron intensity fluctuations.

7.1.3 A collimator long enough to result in a thermal neutron beam with a minimal beam divergence that will reduce scattering contributions and ^{10}B measurement variability with sample thickness. The collimator may be evacuated, filled with air, or an inert gas.

7.1.4 A physical support, preferably adjustable, to mount the standard and the test specimens in the neutron beam.

7.1.5 A neutron detector, usually a boron tri-fluoride (BF_3) filled detector tube. In BF_3 detectors, the pulse amplitudes from neutrons are much larger than the pulses produced by gamma radiation. The pulse height discriminator is normally readily able to bias out the gamma pulses.

7.1.6 Electronic circuitry to count the number of neutrons detected by the neutron detector(s). The electronics generally consist of a pre-amplifier, amplifier, pulse-height discriminator, counting circuits and an appropriate timer

7.1.7 A thermal neutron beam with a cross-sectional area between 0.75 cm^2 and 6.0 cm^2. The diameter of the beam should not exceed the active area of the neutron detector.

8. Hazards

8.1 This test method does not address radiation safety. It is the responsibility of the user of this test method to establish appropriate safety procedures, if necessary.

9. Calibration and Standardization

9.1 A series of standards with uniform, homogenous, and accurately known ^{10}B areal densities is necessary for quantitative interpretation of the counting data acquired in the attenuation measurements. If the standards are not chemically homogenous, the user of this standard must demonstrate that the uniformity of the sample's ^{10}B is sufficient to meet the intention of this standard. These standards shall include ^{10}B areal densities spanning the range of areal densities expected in the test specimens. Calibration standards must have a testing surface area at least twice that of the thermal neutron beam's cross-sectional area

9.2 The number of standards used shall take into consideration the magnitude and range of the sample's target areal density and required accuracy of the measurement. A minimum of three standards shall be used. The facility, calibration standards, and the test samples' areal densities should be considered when determining the spacing of the calibration areal densities. For example, when using a poly-energetic beam, the optimal spacing of the calibration standard's areal densities will not be uniform.

9.3 Aluminum shim plate(s) may be required with the standards to simulate the aluminum in the test specimen. Because the absorption and scattering cross-sections of aluminum are very small, exact replication of the aluminum in the test specimens is not critical. Scattering plays a very minor role in neutron attenuation measurements. The standards shall be shimmed to ensure an equivalent or larger scattering contribution than the test specimen.

9.4 If the material used for calibration standards contains neutron absorbing or scattering nuclides not present in the test specimens, or vice versa, the effect of these nuclides on the accuracy of the measurements shall be addressed.

10. Procedure

10.1 The following procedure describes the method used to measure the calibration standards as well as the samples. Calibration, background, and beam intensity shall be measured each time a set of samples are undergoing investigation, so the measurement of these values is also described as part of the procedure. This particular approach measures all values as counts per measurement period.

10.2 Prepare the neutron source for use. Verify that calibration standards and test specimens are available and ready for use.

10.3 Measure the counting rate for the direct beam (db) with any holders in place.

10.4 Measure the background counting rate (bkg) with a strong absorber at the sample position sufficient to attenuate the neutrons responsible for the measurement.