ATTACHMENT 7A CLARIFICATIONS, GUIDANCE, AND EXCEPTIONS TO ASTM STANDARD PRACTICE C1671-15

The U.S. Nuclear Regulatory Commission (NRC) has determined that American Standard for Testing and Materials (ASTM) Standard Practice C1671-15 (ASTM C1671-15), “Standard Practice for Qualification and Acceptance of Boron Based Metallic Neutron Absorbers for Nuclear Criticality Control for Dry Cask Storage Systems and Transportation Packaging,” with some exceptions, additions, and clarifications, is appropriate for use in review activities. This appendix provides guidance to the staff that supplements guidance provided in Chapters 7, “Materials Evaluation,” and 9, “Acceptance Tests and Maintenance Program Evaluation,” of this standard review plan. Alternative approaches are acceptable if technically supportable.

7A.1 Specific Clarifications, Exceptions, and Guidance

7A.1.1 Use of ASTM C1671-15

The NRC staff considers the terminology and statements within ASTM C1671-15 acceptable guidance with some additions, clarifications, and exceptions delineated below, for reviewing SNF storage casks and transportation packages. ASTM C1671-15 is limited to boron-based metallic neutron absorbers. When used, the applicant is responsible for providing a justification that ASTM C1671-15 is applicable to specific boron-based metallic neutron absorbers in an application.

7A.1.2 Clarification Regarding Use of Section 5.2.1.3 of ASTM C1671-15

If the supplier has shown that process changes do not cause changes in the density, open porosity, composition, surface finish, or cladding (if applicable) of the neutron-absorber material, the supplier should not need to requalify the material with regard to thermal properties or resistance to degradation by corrosion and elevated temperatures.

7A.1.3 Additional Guidance Regarding Use of Section 5.2.5.3 of ASTM C1671-15

Neutron-absorbing materials should undergo testing to simulate submersion and subsequent cask and package drying conditions, as part of a qualifying test program. Clad aluminum and boron carbide (B_4C) neutron-absorbers with open porosities between 1 and 3 percent have exhibited blistering after drying. This blistering was from flash steaming of water that was trapped in pores. The staff is concerned that such blistering could have an adverse impact on fuel retrievability and the ability of the absorber to perform its criticality safety function.

Unclad aluminum and B_4C neutron-absorbing materials with open porosities less than 0.5 volume percent may not be required to undergo simulated submersion and drying tests.

7A.1.4 Clarification Regarding Use of Section 5.2.6.2 of ASTM C1671-15

If a coupon contiguous to every plate of neutron-absorbing material is not examined during acceptance testing, the applicant should conduct the neutron attenuation program with a sufficient number of samples to ensure that the neutron-absorbing properties of the materials meet the minimum required areal density of the neutron absorber. In the past, the staff has accepted the following:

- for neutron-absorbing material with a significant qualification program and nonstatistically derived minimum guaranteed properties, wet chemistry analysis of mixed powder batches followed by additional neutron attenuation testing of a minimum of 10 percent of the neutron poison plates

- sampling plans where at least one neutron transmission measurement is taken for every 2,000 square inches [1.3 square meters] of neutron poison plate material in each lot

- a sampling plan that requires each of the first 50 sheets of neutron-absorber material from a lot, or a coupon taken there from, be tested (by neutron attenuation). Thereafter, coupons shall be taken from 10 randomly selected sheets from each set of 50 sheets. This 1-in-5 sampling plan shall continue until there is a change in lot or batch of constituent materials of the sheet (i.e., B_4C powder or aluminum powder) or change in the process. A measured value less than the required minimum areal density of boron-10 during the reduced inspection is defined as nonconforming, along with other contiguous sheets, and mandates a return to 100 percent inspection for the next 50 sheets.

7A.1.5 Additional Guidance Regarding Use of Sections 5.2.6.2 and 5.3.4.1 of ASTM C1671-15

The applicant should clearly state the minimum areal density of boron-10 present in each type of neutron-absorbing material used in the calculation of the effective neutron multiplication factor, k_{eff}, in the Acceptance Tests and Maintenance Program section of the application.

It has been the staff’s practice to limit the credit for neutron-absorber materials to only 75 percent of the minimum amount of boron-10 confirmed by acceptance tests. The staff has accepted up to 90-percent credit in certain cases where the absorber materials are shown by neutron attenuation testing of production lots to be effectively homogeneous.

If 90-percent credit is taken for the efficacy of the neutron absorber, methods other than neutron attenuation should be used only as verification or partial substitution for attenuation tests. The applicant should conduct benchmarking of other methods against neutron attenuation testing periodically throughout acceptance testing, under appropriate attenuation conditions and with proper sample sizes. This should be done to confirm the adequacy of the proposed methods, as the staff considers direct measurement of neutron attenuation to be the most reliable method of measuring the expected neutron-absorbing behavior of the poison plates.

Direct neutron attenuation measurements are only expected for the qualification of alternative characterization methods (e.g., wet chemistry analyses) when only 75-percent credit is taken for the boron-10 areal density of the neutron-absorbing material. Once qualified and benchmarked, neutron attenuation is no longer expected for acceptance testing, as the alternative method is considered properly validated by neutron attenuation.

Applicants should be encouraged to provide statistically significant data showing the correspondence between neutron attenuation testing and wet chemistry data and the precision of both methods. Such data may permit the partial substitution of neutron attenuation measurements with chemical methods for materials receiving 90-percent credit.

7A.1.6 Additional Guidance Regarding Use of Section 5.2.6.2(2) of ASTM C1671-15

The size of the collimated neutron beam should be specified for attenuation testing, and limited to 2.54 centimeters (cm) [1 inch] in diameter, with a tolerance of 10 percent. In the past, the NRC staff has had concerns that attenuation measurements conducted with neutron beams greater than 1-cm [0.4-inch] diameter may lack the resolution to detect localized regions of the neutron-absorbing material that have a low concentration of boron-10. The staff conducted an independent criticality study using an SNF transportation package to determine if neutron attenuation measurements using beam sizes in excess of 1 cm [0.4-inch] were unable to detect localized regions in the neutron-absorbing material deficient in neutron absorber. In the study, the staff assumed that the neutron absorber boron-10 arranged itself into a “checkerboard” fashion of alternating boron-rich and boron-deficient regions, where the boron concentration was 50 percent greater and 50 percent less than the average amount of boron in a homogenous plate of boron and aluminum. The staff considers this hypothetical configuration bounding of any possible “real-life” defects that might occur in actual manufacturing. In the simulations, the staff considered two models. One model permitted a nonconstant density, where boron was removed from boron-deficient regions and directly added to adjacent regions. In the second model, the quantity of aluminum and carbon were adjusted in each of the regions so that the overall mass density of the plate remained uniform. The sizes of the boron-rich and boron-deficient regions were then gradually increased, and changes in k_{eff} were observed. This is plotted in Figure 7A-1.

The results of the study showed no significant difference in k_{eff} when the size of the heterogeneities (the length of each boron-deficit or -rich region) increased from 1 cm to 2.54 cm. It should be noted that the staff conducted this study on a single transportation package design. The staff considers the heterogeneities introduced in the neutron-absorbing materials sufficiently exaggerated such that this study may be used to make a general determination.

As such, the staff regards collimated neutron beams with nominal diameters between 1 cm and 2.54 cm, with tolerances of 10 percent, as sufficiently capable of detecting defects within the neutron-absorbing material, and should be considered acceptable for the purposes of qualification and acceptance testing of neutron-absorbing materials.

7A.1.7 Additional Guidance Regarding Use of Section 5.2.6.3 of ASTM C1671-15

The maximum permissible thickness deviation of the neutron-absorbing material should be specified, and actions should be taken if the thickness is outside the permissible limits.

During the production of neutron-absorbing materials, minor deviations from the specified physical dimensions are expected. The applicant should discuss these deviations, and, in particular, variations of the neutron-absorbing material thickness in the application in a way that can be referenced in the certificate of compliance. The applicant should specify the maximum permissible thickness deviation (for both over and under tolerances) and the actions taken if the thickness is outside the permissible limits. This is done to assure adequate performance of the neutron-absorbing materials. In the past, the staff has allowed acceptance testing where a minimum plate thickness is specified, which permitted local depressions as long as the depressions were no more than 0.5 percent of the area on any given plate, and the thickness at their location was not less than 90 percent of the minimum design thickness.

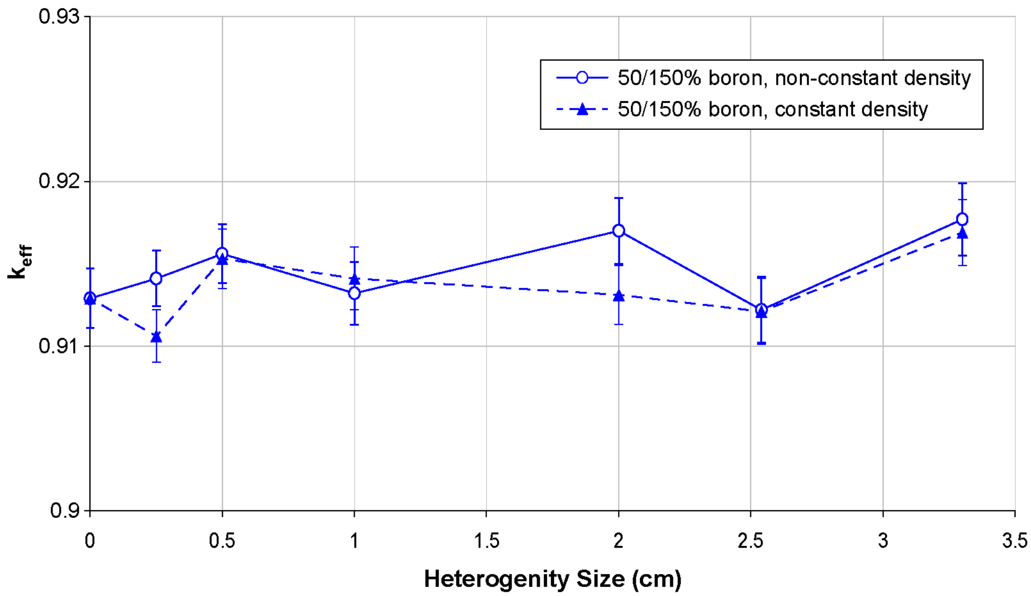

Figure 7A-1 Plot of the effective neutron multiplication factor, k_{eff}, as a function of heterogeneity size

7A.1.8 Additional Guidance Regarding Use of Section 5.2.6.4 of ASTM C1671-15

The applicant's acceptance test should specify a visual inspection procedure that describes the nominal inspection criteria. Visual inspection should be conducted on all neutron-absorbing materials intended for service.

As part of the visual inspection of the neutron-absorbing material, it is important to ensure that there are no defects that might lead to problems in service such as delaminations or cracks that could appear on clad neutron-absorbing materials. The concern is that gross defects on the plate or plate edge may lead to separations, especially from vibrations during transportation; this could lead to a lack of absorber capability over the missing or misplaced region within a plate material.

7A.1.9 Clarification Regarding Use of Sections 5.2.7 and 5.3 of ASTM C1671-15

The applicant should include a description of the key processes, major operations process controls, and the acceptance testing steps of neutron-absorbing materials in the Acceptance Tests and Maintenance Program section of the application.

7A.1.10 Additional Guidance Regarding Use of Section 5.2.7.1 of ASTM C1671-15

In addition to the guidance provided in Section 5.2.7.1 of ASTM 1671-15, another key process to consider is a change of the matrix alloy, or a change in the material's heat treatment, which may cause an undesirable reaction to occur within the matrix itself or between the matrix and a secondary phase.

7A.1.11 Additional Guidance Regarding Use of Section 5.4 of ASTM C1671-15

Neutron-absorbing materials intended for criticality control should have a safety classification of "A," in accordance with NUREG/CR-6407.

7A.2 References

American Society for Tests and Materials, C1671-15, "Standard Practice for Qualification and Acceptance of Boron Based Metallic Neutron Absorber Materials for Nuclear Criticality Control for Dry Cask Storage Systems and Transportation Packaging," ASTM International, 2015.

NUREG/CR-6407, U.S. Nuclear Regulatory Commission, "Classification of Transportation Packaging and Dry Spent Fuel Storage System Components According to Importance to Safety," Idaho National Engineering Laboratory, INEL-95/0551, February 1996.