

1 **Division of Spent Fuel Storage and Transportation**
2 **Interim Staff Guidance-23**

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5 **Issue: Application of ASTM Standard Practice C1671-07 when performing**
6 **technical reviews of spent fuel storage and transportation packaging**
7 **licensing actions.**
8

9 **Introduction:**

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11 The standard review plans for storage of spent nuclear fuel and transportation of fissile
12 materials do not address, in detail, the technical considerations for crediting the neutron
13 absorber content of metal matrix composites used for preventing nuclear criticality. The Division
14 of Spent Fuel Storage and Transportation (SFST) considers the application of acceptance
15 criteria and methodology described in the recently developed American Standard for Testing
16 and Materials (ASTM) standard practice C1671-07, "Standard Practice for Qualification and
17 Acceptance of Boron Based Metallic Neutron Absorbers for Nuclear Criticality Control for Dry
18 Cask Storage Systems and Transportation Packaging,"¹ with some exceptions, additions, and
19 clarifications appropriate for staff use in their review activities. This Interim Staff Guidance (ISG)
20 provides guidance to the staff and is not a regulatory requirement. Alternative approaches are
21 acceptable if technically supportable.
22

23 **Discussion:**

24
25 Use of ASTM C1671-07

26 The staff considers the terminology and statements within ASTM Standard Practice C1671-07
27 as acceptable guidance with some additions, clarifications and exceptions delineated below, for
28 reviewing spent nuclear fuel storage cask and transportation packages, and therefore
29 appropriate for use by the Spent Fuel Storage and Transportation (SFST) staff.
30

31 Clarification regarding use of Section 5.2.1.3 of ASTM C1671-07

32 If the supplier has shown that process changes do not cause changes in the density, open
33 porosity, composition, surface finish, or cladding (if applicable) of the neutron absorber material,
34 the supplier should not be required to re-qualify the material with regard to thermal properties or
35 resistance to degradation by corrosion and elevated temperatures.
36

37 Exception to Section 5.2.3 of ASTM C1671-07

38 The staff does not accept the following language in Section 5.2.3: "Requalification for a
39 qualified neutron absorber material produced by a new supplier may consist of a review of key
40 processes and process controls to verify that they have been adequately replicated by the new
41 supplier."
42

43 Following a change of supplier (excluding the wholesale purchase of the fabricator), the
44 fabricator should do a review of key process and controls and perform qualification testing
45 demonstrating that the neutron absorbing material has the specified mechanical properties,
46 required density, limits on porosity, and (if applicable) resistance to blistering.
47
48

49 Additional guidance regarding use of Section 5.2.5.3 of ASTM C1671-07

50 The following additional guidance applies to Section 5.2.5.3: Neutron absorbing materials
51 should undergo testing to simulate submersion and subsequent cask drying conditions, as part
52 of a qualifying test program.

53
54 Clad aluminum/boron carbide neutron absorbers with open porosities between one and three-
55 percent have exhibited blistering after canister drying. This blistering was due to flash steaming
56 of water that was trapped in pores. The staff is concerned that such blistering could have an
57 adverse impact on fuel retrievability.

58
59 Unclad aluminum / boron carbide neutron absorbing materials with open porosities less than
60 0.5-volume percent may not be required to undergo simulated submersion and drying tests.

61
62 Clarification regarding use of Section 5.2.6.2 of ASTM C1671-07

63 If a coupon contiguous to every plate of neutron absorbing material is not examined
64 during acceptance testing, the neutron attenuation program should be done with a
65 sufficient number of samples to ensure that the neutron absorbing properties of the
66 materials meet the minimum required areal density of the neutron absorber. In the past
67 the staff has accepted:

68
69 1) (For a neutron absorbing material with a significant qualification program and non-statistically
70 derived minimum guaranteed properties), wet chemistry analysis of mixed powder batches
71 followed by additional neutron attenuation testing of a minimum of 10% of the neutron poison
72 plates.

73
74 2) Sampling plans where at least one neutron transmission measurement is taken for 2000
75 square inches of neutron poison plate material in each lot.

76
77 3) A sampling plan which requires: that each of the first 50 sheets of neutron absorber material
78 from a lot, or a coupon taken there from, be tested (by neutron attenuation). Thereafter,
79 coupons shall be taken from 10 randomly selected sheets from each set of 50 sheets. This 1 in
80 5 sampling plan shall continue until there is a change in lot or batch of constituent materials of
81 the sheet (i.e., boron carbide powder or aluminum powder) or a process change. A measured
82 value less than the required minimum areal density of boron-10 during the reduced inspection is
83 defined as nonconforming, along with other contiguous sheets, and mandates a return to 100%
84 inspection for the next 50 sheets.

85
86 Additional guidance regarding use of Section 5.2.6.2 and 5.3.4.1 of ASTM C1671-07

87 The following additional guidance applies to Section 5.2.6.2: The minimum areal density of
88 boron-10 present in each type of neutron absorbing material used in the calculation of the
89 effective neutron multiplication factor, k_{eff} , must be clearly stated in Chapter 8 of a Part 71
90 application, and the proposed Technical Specifications in a Part 72 application.

91
92 Based on recommendations in NUREG-1567³, NUREG-1609⁴, and NUREG-1617⁵ it has been
93 the staff's practice to limit the credit for neutron absorber materials to only 75-percent of the
94 minimum amount of boron-10 confirmed by acceptance tests. The staff has permitted up to 90-
95 percent credit in certain cases where the absorber materials are shown by neutron attenuation
96 testing of production lots to be effectively homogeneous.

97

98 If 90-percent credit is taken for the efficacy of the neutron absorber, methods other than neutron
99 attenuation should be used only as verification or partial substitution for attenuation tests.
100 Benchmarking of other methods, against neutron attenuation testing, should be done
101 periodically throughout acceptance testing, under appropriate attenuation conditions and with
102 proper sample sizes. This should be done to confirm the adequacy of the proposed methods,
103 as direct measurements of neutron attenuation are the most reliable method of measuring the
104 expected neutron absorbing behavior of the poison plates.

105
106 For neutron absorbing materials for which 75-percent credit is taken, direct neutron attenuation
107 measurements should be required only as part of a qualification program, which should include
108 benchmarking for other methods used to determine the boron-10 areal density. Once qualified
109 and benchmarked, the alternative methods which have been validated by attenuation
110 measurements, such as wet chemistry analyses, are sufficient to verify the minimum areal
111 density of the neutron absorbing material during acceptance testing.

112
113 Applicants should be encouraged to provide statistically significant data showing the
114 correspondence between neutron attenuation testing and wet chemistry data and the precision
115 of both methods. Such data may permit the partial substitution of neutron attenuation
116 measurements with chemical methods for materials receiving 90% credit.

117
118 Clarification to Section 5.2.6.2(1) of ASTM C1671-07

119 Homogenous neutron absorbing materials with uniform absorption properties such as zirconium
120 diboride (ZrB_2) or hot-pressed boron carbide (B_4C), (typically paired with aluminum shims) or
121 heterogeneous calibration standards with pedigrees traceable to widely recognized institutions
122 (e.g., national laboratories) are acceptable as neutron attenuation calibration standards.

123
124 Additional guidance regarding use of Section 5.2.6.2(2) of ASTM C1671-07

125 The following additional guidance applies to Section 5.2.6.2(2): The size of the collimated
126 neutron beam should be specified for attenuation testing, and limited to 2.54-cm diameter, with
127 a tolerance of 10-percent.

128
129 In the past, some staff members have had concerns that attenuation measurements conducted
130 with neutron beams greater than 1-cm diameter may lack the resolution to detect localized
131 regions of the neutron absorbing material which have a low concentration of boron-10. The staff
132 conducted an independent criticality study using a spent nuclear fuel transportation package to
133 determine if neutron attenuation measurements using beam sizes in excess of 1-cm are unable
134 to detect localized regions in the neutron absorbing material deficient in neutron absorber. In
135 the study, it was assumed that the neutron absorber boron-10 arranged itself into a
136 “checkerboard” fashion of alternating boron-rich and boron-deficient regions where the boron
137 concentration was 50-percent greater and 50-percent less than the average amount of boron in
138 a homogenous plate of boron and aluminum. The staff considers this hypothetical configuration
139 bounding of any possible “real-life” defects which might occur in actual manufacturing. In the
140 simulations, two models were considered. One model permitted a non-constant density, where
141 boron was removed from boron-deficient regions and directly added to adjacent regions. In the
142 second model, the quantity of aluminum and carbon were adjusted in each of the regions so
143 that the overall mass density of the plate remained uniform. The sizes of the boron-rich and
144 boron deficient regions were then gradually increased, and changes in k_{eff} were observed. This
145 is plotted in Figure 1.

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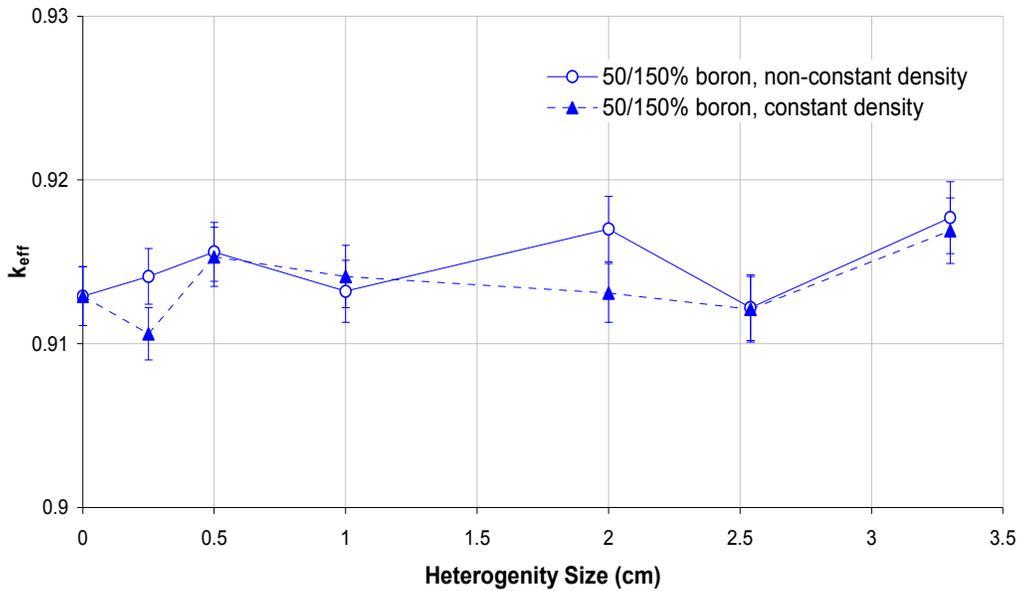


Figure 1: Plot of the Effective Neutron Multiplication Factor, k_{eff} , as a Function of Heterogeneity size

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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 this study was conducted on a single transportation package design. The staff considers the heterogeneities introduced in the neutron absorbing materials sufficiently exaggerated that this study suitably reflects the basis for 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.

163 Additional guidance regarding use of Section 5.2.6.3 of ASTM C1671-07

164 The following additional guidance applies to Section 5.2.6.3: A visual inspection procedure
165 which describes the nominal inspection criteria should be specified in the applicant's
166 acceptance tests. Visual inspection should be conducted on all neutron absorbing materials
167 intended for service.

168
169 As part of the visual inspection of the neutron absorbing material, it is important to ensure that
170 there are no defects that might lead to problems in service; such as delaminations or cracks that
171 could appear on clad neutron absorbing materials. The concern is that gross defects on the
172 plate or plate edge may lead to separations, especially from vibrations during transportation; this
173 could lead to a lack of absorber capability over the missing or misplaced region within a plate
174 material.

175
176 Additional guidance regarding use of Section 5.2.6.3 of ASTM C1671-07

177 The following additional guidance applies to Section 5.2.6.3: The maximum permissible
178 thickness deviation of the neutron absorbing material should be specified, and actions to be
179 taken if the thickness is outside the permissible limits.

180
181 During the production of neutron absorbing materials, minor deviations from the specified
182 physical dimensions are expected. These deviations, and in particular, variations of the neutron
183 absorbing material thickness should be discussed in the application, in a way that is referenced
184 in the Certificate of Compliance. The applicant should specify the maximum permissible
185 thickness deviation, and the actions taken if the thickness is outside the permissible limits. This
186 is done to ensure adequate performance of the neutron absorbing materials. In the past, the
187 staff have allowed acceptance testing where a minimum plate thickness is specified, which
188 permitted local depressions, so long as the depressions were no more than 0.5-percent of the
189 area on any given plate, and the thickness at their location is not less than 90-percent of the
190 minimum design thickness.

191
192 Clarification regarding use of Sections 5.2.7 and 5.3 of ASTM C1671-07

193 When implementing Sections 5.2.7 and 5.3, a description of the key processes, major
194 operations process controls, and the acceptance testing steps of neutron absorbing materials
195 should be included in Chapter 8 of a Part 71 application, and the proposed Technical
196 Specifications in a Part 72 application.

197
198 Additional guidance regarding use of Section 5.2.7.1 of ASTM C1671-07

199 In addition to the guidance provided in Section 5.2.7.1, a change of the matrix alloy, or a change
200 in the material's heat treatment which may cause an undesirable reaction to occur within the
201 matrix itself or between the matrix and a secondary phase should also be considered key
202 processes.

203
204 Heat treatments which cause the precipitation of water-soluble aluminum carbide (Al_4C_3) or
205 embrittling $Al_xB_yC_z$ phases could degrade the mechanical properties of the material.

206
207 Additional guidance regarding use of Section 5.4 of ASTM C1671-07

208 The following additional guidance applies to Section 5.4: Title 10 CFR Part 71 and Part 72
209 applications, neutron absorbing materials intended for criticality control should always have a
210 safety classification of "A", under the guidance of NUREG/CR-6407.⁷

211 **Regulatory Basis:**

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213 10 CFR 71.33(b)(4): The application must include a description of the proposed
214 package in sufficient detail to identify the package accurately and provide a sufficient
215 basis for evaluation of the package. The description must include extent of reflection, the
216 amount and identity of nonfissile materials used as neutron absorbers or moderators,
217 and the atomic ratio of moderator to fissile constituents;

218
219 10 CFR 71.55(b): Except as provided in paragraph (c) or (g) of this section, a package
220 used for the shipment of fissile material must be so designed and constructed and its
221 contents so limited that it would be subcritical if water were to leak into the containment
222 system, or liquid contents were to leak out of the containment system so that, under the
223 following conditions, maximum reactivity of the fissile material would be attained: (1) The
224 most reactive credible configuration consistent with the chemical and physical form of
225 the material; (2) Moderation by water to the most reactive credible extent; and (3) Close
226 full reflection of the containment system by water on all sides, or such greater reflection
227 of the containment system as may additionally be provided by the surrounding material
228 of the packaging.

229
230 10 CFR 71.55(e): A package used for the shipment of fissile material must be so
231 designed and constructed and its contents so limited that under the tests specified in §
232 71.73 ("Hypothetical accident conditions"), the package would be subcritical. For this
233 determination, it must be assumed that: (1) The fissile material is in the most reactive
234 credible configuration consistent with the damaged condition of the package and the
235 chemical and physical form of the contents; (2) Water moderation occurs to the most
236 reactive credible extent consistent with the damaged condition of the package and the
237 chemical and physical form of the contents; and (3) There is full reflection by water on all
238 sides, as close as is consistent with the damaged condition of the package.

239
240 10 CFR 71.59(a)(2): A fissile material package must be controlled by either the shipper
241 or the carrier during transport to assure that an array of such packages remains
242 subcritical. To enable this control, the designer of a fissile material package shall derive
243 a number "N" based on all the following conditions being satisfied, assuming packages
244 are stacked together in any arrangement and with close full reflection on all sides of the
245 stack by water: two times "N" damaged packages, if each package were subjected to the
246 tests specified in § 71.73 ("Hypothetical accident conditions") would be subcritical with
247 optimum interspersed hydrogenous moderation

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249 10 CFR 71.64(a)(1)(iii): A package for the shipment of plutonium by air subject to §
250 71.88(a)(4), in addition to satisfying the requirements of §§ 71.41 through 71.63, as
251 applicable, must be designed, constructed, and prepared for shipment so that under the
252 tests specified in § 71.74 ("Accident conditions for air transport of plutonium") -- A single
253 package and an array of packages are demonstrated to be subcritical in accordance with
254 this part, except that the damaged condition of the package must be considered to be
255 that which results from the plutonium accident tests in § 71.74, rather than the
256 hypothetical accident tests in § 71.73.

257
258 10 CFR 72.124(b): Methods of criticality control. When practicable, the design of an
259 ISFSI or MRS must be based on favorable geometry, permanently fixed neutron
260 absorbing materials (poisons), or both. Where solid neutron absorbing materials are

261 used, the design must provide for positive means of verifying their continued efficacy.
262 For dry spent fuel storage systems, the continued efficacy may be confirmed by a
263 demonstration or analysis before use, showing that significant degradation of the
264 neutron absorbing materials cannot occur over the life of the facility.

265
266 10 CFR 72.154(a): The licensee, applicant for a license, certificate holder, and
267 applicant for a Certificate of Compliance shall establish measures to ensure that
268 purchased material, equipment, and services, whether purchased directly or
269 through contractors and subcontractors, conform to the procurement documents.
270 These measures must include provisions, as appropriate, for source evaluation
271 and selection, objective evidence of quality furnished by the contractor or
272 subcontractor, inspection at the contractor or subcontractor source, and
273 examination of products upon delivery.

274
275 10 CFR 72.236(c): (Certificate of Compliance holder only) The spent fuel
276 storage cask must be designed and fabricated so that the spent fuel is
277 maintained in a subcritical condition under credible conditions.

278
279 **Applicability:**

280
281 This guidance applies to reviews of dry cask storage and transport package designed for fissile
282 material conducted in accordance with NUREG-1536², "Standard Review Plan for Dry Cask
283 Storage Systems" (January 1997); NUREG-1567³, "Standard Review Plan for Spent Fuel Dry
284 Storage Facilities" (March 2000); NUREG-1609⁴, "Standard Review Plan for Transportation
285 Packages for Radioactive Material" (March 1999); NUREG-1617⁵, "Standard Review Plan for
286 Transportation Packages for Spent Nuclear Fuel" (March 2000); and Interim Staff Guidance 15
287 (ISG-15)⁶, "Materials Evaluation" (January 2001).

288
289 **Technical Review Guidance:**

- 290
- 291 • Clarification on use of Section 5.2.1.3:
292 This clarification describes certain physical properties of the neutron absorbing material
293 which, when shown not to change, would not require requalification of the neutron absorbing
294 material with regards to corrosion or thermal degradation behavior.
295
 - 296 • Exception to Section 5.2.3:
297 New suppliers should perform a limited requalification of the neutron absorbing material.
298
 - 299 • Additional guidance on use of Section 5.2.5.3:
300 Testing should be added to simulate vacuum drying after submersion.
301

- 302
- 303 • Clarification on use of Section 5.2.6.2:
- 304 Acceptance testing sampling is dependent on the statistical validity of qualification testing.
- 305 Previously approved sampling programs for acceptance tests are presented.
- 306
- 307 • Additional guidance on use of Section 5.2.6.2 and 5.3.4.1:
- 308 Methods other than neutron attenuation may be appropriate for acceptance testing of the
- 309 neutron absorbing material, depending on the amount of “credit” taken for the neutron
- 310 absorber.
- 311
- 312 • Exception to Section 5.2.6.2(1):
- 313 Heterogeneous materials are permitted as neutron attenuation calibration standards if they
- 314 are traceable to a widely recognized source, such as a national laboratory.
- 315
- 316 • Additional guidance on use of Section 5.2.6.2(2):
- 317 The neutron beam diameter used for attenuation measurements is limited to 1-inch with 10-
- 318 percent tolerance.
- 319
- 320 • Additional guidance on use of Section 5.2.6.3:
- 321 A visual inspection procedure for 100-percent of the plates of neutron absorbing material
- 322 should be specified in the application.
- 323
- 324 • Additional guidance on use of Section 5.2.6.3:
- 325 Maximum possible thickness variations in the neutron absorbing material should be
- 326 discussed in the application.
- 327
- 328 • Clarification of use of Sections 5.2.7 and 5.3:
- 329 Key processes and testing criteria should be placed in Chapter 8 of the Part 71 application
- 330 or in the Technical Specifications of a Part 72 application.
- 331
- 332 • Additional guidance on use of Section 5.2.7.1:
- 333 Changes to processing which may adversely affect the microstructure of the matrix may
- 334 require re-qualification of the neutron absorbing material.
- 335
- 336 • Additional guidance on use of Section 5.4:
- 337 For Part 71 and Part 72 applications, neutron absorbing materials should be given a safety
- 338 classification of “A”, under the guidance of NUREG/CR-6407.⁷
- 339

340 **Recommendations:**

341

342 The staff recommends that ASTM Standard C1671-07, along with the qualifying statements

343 found in this document, be considered for use in the evaluation of licensing actions which rely

344 upon boron-based metallic neutron absorber materials for nuclear criticality control in dry cask

345 storage systems and transportation packaging.

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Approved: _____/Draft/_____, 2010
Vonna Ordaz, Director
Division of Spent Fuel Storage and Transportation

References:

- ¹ ASTM C 1671-07, “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, August 2007.
- ² NUREG-1536, “Standard Review Plan for Dry Cask Storage Systems,” Spent Fuel Project Office, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, D.C. January 1997.
- ³ NUREG-1567, “Standard Review Plan for Spent Fuel Dry Storage Facilities,” Spent Fuel Project Office, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, D.C. March 2000.
- ⁴ NUREG-1609, “Standard Review Plan for Transportation Packages for Radioactive Material” Spent Fuel Project Office, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, D.C. March 1999.
- ⁵ NUREG-1617, “Standard Review Plan for Transportation Packages for Spent Nuclear Fuel,” Spent Fuel Project Office, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, D.C. March 2000.
- ⁶ Interim Staff Guidance 15 (ISG-15), “Materials Evaluation,” Spent Fuel Project Office, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, D.C. January 2000.
- ⁷ NUREG/CR-6407, “Classification of Transportation Packaging and Dry Spent Fuel Storage System Components According to Importance to Safety,” Idaho National Engineering Laboratory, ID. February 1996.