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Ms. Cindy Bladey
Chief, Rules, Announcements, and Directives Branch, Office of Administration
Mail Stop: 3WFN–06–44M
U.S. Nuclear Regulatory Commission
Washington, DC 20555–0001

AREVA Inc. Response to Request for Public Comment on the Draft Regulatory Guides Supporting the Proposed 10 CFR 50.46c Performance-Based Emergency Core Cooling Systems Cladding Acceptance Criteria [DG–1261, "Conducting Periodic Testing for Breakaway Oxidation Behavior" (Docket ID NRC–2012–0041), DG–1262, "Testing for Post Quench Ductility" (Docket ID NRC–2012–0042), and DG–1263, "Establishing Analytical Limits for Zirconium-Based Alloy Cladding" (Docket ID NRC–2012–0043)]

Dear Ms. Bladey:

AREVA Inc. (AREVA) submits the enclosed comments for consideration by the U.S. Nuclear Regulatory Commission (NRC). These comments are in response to the NRC request for public comment on the proposed Performance-Based Emergency Core Cooling Systems (ECCS) Cladding Acceptance Criteria (Federal Register Vol. 79, No. 56, 16106, March 24, 2014; Docket ID NRC-2008-0332, (Reference 1)). The enclosures provide formal comments on the Draft Regulatory Guides DG-1261, DG-1262 and DG-1263 (References 2, 3 and 4). Note that for convenience, both the comments on the proposed rule and the draft regulatory guides are enclosed.

AREVA also participated with the Regulatory Technical Advisory Committee (Reg TAC) of the EPRI Fuel Reliability Program in developing the Industry responses to the 10 CFR 50.46c draft rule language that NEI will be submitting to the NRC. AREVA is in general concurrence with the Industry comments contained in the NEI submittal except as superseded by the enclosed AREVA specific comments on the draft rule language.

If you have any questions related to this information, please contact Alan Meginnis by telephone at (509) 375-8266, or by e-mail at Alan.Meginnis@areva.com

Sincerely,

Pedro Salas, Director
Regulatory Affairs
AREVA Inc.

SUNSI Review Complete
Template = ADM – 013
E-RIDS= ADM-03
Add= M. Flanagan (mef)

References

Ref. 1: Federal Register Vol. 79, No. 56, 16106, March 24, 2014; Docket ID NRC-2008-0332 (ML12283A174).

Ref. 2: Draft Regulatory Guide DG-1261, "Conducting Periodic Testing for Breakaway Oxidation Behavior," March 2014, Docket ID NRC–2012–0041, (ML12284A324).

Ref. 3: Draft Regulatory Guide DG-1262, "Testing for Post Quench Ductility," March 2014, Docket NRC– 2012–0042 (ML12284A325).

Ref. 4: Draft Regulatory Guide DG-1263, "Establishing Analytical Limits for Zirconium-Based Alloy Cladding," March 2014, Docket ID and NRC–2012–0043 (ML12284A323).

Enclosures:

1. AREVA Comments on 10 CFR 50.46c Proposed Rule
2. AREVA Response to Proposed 10 CFR 50.46c Supplementary Information Section VII Selected Questions
3. AREVA Comments on Draft Regulatory Guide 1261
4. AREVA Comments on Draft Regulatory Guide 1262
5. AREVA Comments on Draft Regulatory Guide 1263

cc: J. G. Rowley
A. Bone
P. M. Clifford
T. Inverso
Project 728

bcc: NRC:14:053

R. L. Baxter
M. C. Bryan
F. Burtak
S. E. Cole
F. Curca Tivig
K. V. Delano
B. M. Dunn
G. F. Elliott
K. Elliott
R. S. Freeman
N. L. Garner
L. M. Gerken
L. T. Gucwa
G. P. Hatchett
J. S. Holm
N. E. Hottle
J. G. Ingham
D. A. Kelley
D. J. Kowalski
R. J. Land
S. L. McFaden
A. B. Meginnis
J. L. Musgrave
P. A. Opsal
R. M. Pederson
G. A. Peters
J. M. Romine
T. E. Ryan
P. Salas
R. R. Schnepp
D. K. White
T. S. Wilkerson

Enclosure 1

AREVA Comments on 10 CFR 50.46c Proposed Rule

Comment #1: Page 16139, 50.46c(b) Definitions, "ECCS evaluation model"

Statement in Rule: The proposed Rule states that "ECCS evaluation model" includes "specification of those portions of analysis not included in computer programs, values of parameters, [emphasis added] and all other information necessary to specify the calculational procedure."

Description of Concern: The evaluation model does not include plant-specific input values that describe physical plant characteristics, such as operating pressure or HPSI flow rates.

Basis for concern: Plant-specific inputs are not part of the approval of a generic evaluation model. The phrase "values of parameters" can be misinterpreted as including these values. If "values of parameters" is not clarified, errors in plant specific inputs that are subject to other reporting mechanisms could fall under the 10 CFR 50.46c(m) reporting requirements.

Proposal: Modify the phrase "values of parameters" to "value of parameters (excluding plant specific input parameters)."

Basis of proposal: n/a

Comment #2: Page 16139, 50.46c(b) Definitions, "Debris evaluation model" ,

Statement in Rule: "The debris evaluation model is used, along with the probabilistic risk assessment (PRA), to quantify the portion of core damage frequency and large early release frequency attributable to debris."

Description of Concern: As written, the definition applies only to models used in connection with a risk informed evaluation of debris and long term cooling. There is also an alternative deterministic debris evaluation model and the lack of differentiating may create confusion.

Basis for concern: n/a

Proposal: Relabel the section as "Debris evaluation model for risk informed evaluations" or restructure the definition to apply to both the risk informed evaluation and the deterministic evaluation.

Basis of proposal: n/a

Comment #3: Page 16140, 50.46c(d)(3)(i)(B) Required documentation,

Statement in Rule: "A complete listing of each computer program, in the same form as used in the ECCS evaluation model, must be furnished to the NRC upon request."

Description of Concern: The required documentation being requested is unclear and could be misinterpreted.

Basis for concern: It is unclear if the NRC is requesting the source code or simply a list of program names and their executed versions.

Proposal: Replace with "The source code for each computer program used in the ECCS evaluation model must be furnished to the NRC upon request."

Basis of proposal: n/a

Comment #4: Page 16140, 50.46c(d)(3)(iii) Required documentation

Statement in Rule: "Appropriate sensitivity studies must be performed for each ECCS evaluation model, to evaluate the effect on the calculated results of variations in noding, phenomena assumed in the calculation to predominate, including pump operation or locking, and values of parameters over their applicable ranges. For items to which results are shown to be sensitive, the choices made must be justified."

Description of Concern: The application of the statement is not specified to the evaluation model type: Realistic vs. Appendix K. Appendix K provides a prescriptive, conservative approach deemed to be acceptable to the NRC. Extensive sensitivities studies on the prescriptive Appendix K approach are not necessary.

Basis for concern: This section could potentially require a large increase in sensitivity studies for deterministic, Appendix K, evaluation model analyses.

Proposal: Modify the section as follows:

> Appropriate sensitivity studies must be performed for each Best Estimate ECCS evaluation model, to evaluate the effect on the calculated results of variations in noding, phenomena assumed in the calculation to predominate, including pump operation or locking, and values of parameters over their applicable ranges. For items to which results are shown to be sensitive, the choices made must be justified.

Basis of proposal: n/a

Comment #5: Page 16141, 50.46c(g)(1)(i),(ii),(iii) Fuel performance criteria

Statement in Rule: The first three fuel performance criteria are termed "Peak cladding temperature," "Cladding embrittlement," and "Breakaway oxidation."

Description of Concern: Peak cladding temperature and breakaway oxidation are also measures to protect against cladding embrittlement.

Basis for concern: Criterion (ii) has changed from "Maximum local oxidation" to "Cladding embrittlement" since it now contains both a maximum local oxidation and cladding temperature limit. However, this implies that Criterion (i) and Criterion (iii) are not associated with embrittlement.

Proposal: Modify headings to appropriately categorize the criteria. Criterion (ii) could be titled "Integral Time at Temperature."

Basis of proposal: The proposal is consistent with the statement of considerations in the current FRN, page 16115.

Comment #6: Page 16141, 50.46c(g)(1)(i) Peak cladding temperature

Statement in Rule: "the calculated maximum fuel element cladding temperature shall not exceed 2200 °F."

Description of Concern: This section is redundant with Section (g)(1)(ii) and is not performance based. Furthermore, Section (g)(1)(ii) explicitly nullifies Criterion (g)(1)(i) under certain conditions.

Basis for concern: n/a

Proposal: Remove this section. If necessary, Section (g)(1)(ii) could be augmented to state: "For peak cladding temperatures above those previously justified for postquench ductility considerations, phenomena other than ductility may have to be considered."

Basis of proposal: See AREVA Response to NRC Question #1.

Comment #7: Page 16141, 50.46c(g)(1)(v) Long-term cooling

Statement in Rule: "An analytical limit on long-term peak cladding temperature shall be established that corresponds to the ductile-to-brittle transition for the zirconium-alloy cladding material determined using an NRC-approved experimental technique."

Description of Concern: A single peak cladding temperature is not appropriate for the long-term cooling ductile-to-brittle transition or additional degradation mechanisms possible in the long-term.

Basis for concern: n/a

Proposal: The criterion could be modified as follows: "An analytical limit that corresponds to the long-term cladding degradation phenomena shall be established and approved by the NRC."

Basis of proposal: The proposed wording allows for the identification of all the potential degradation mechanisms and the appropriate establishment of a requirement.

Comment #8: Pages 16141 to 16143, 50.46c(m) and associated sub-sections

Statement in Rule: The proposed Rule states that "Each entity [emphasis added] subject to the requirements of this section must comply with paragraphs (m)(1) through (3) of this section. Each entity [emphasis added] demonstrating acceptable long-term core cooling under the provisions of paragraph (e) of this section shall also comply with the requirements of paragraph (m)(4) of this section."

Description of Concern: Entity is too broad a category.

Basis for concern: The responsibility for error-reporting is unclear with this term.

Proposal: "Entity" should be replaced with "licensee or licensee-applicant" or clarified as appropriate, throughout the rule.

Basis of proposal: Section 50.46c(a) uses entities as those who design, construct or operate a light water reactor. The broad term "entity" could lead to misinterpretation of intent. For example, if misinterpreted, the plant designers would maintain responsibility for reporting throughout the plant's lifetime. Furthermore, individuals and organization other than the licensees would be required to set schedules for the licensees.

Comment #9: Page 16141, 50.46c(m)(2) Significant change or error in the ECCS evaluation model

Statement in Rule: "a significant change or error in an ECCS evaluation model is one that results in a calculated [emphasis added]"

Description of Concern: The word "calculated" could be misinterpreted as requiring the analysis to be reperformed.

Basis for concern: n/a

Proposal: Use "estimated" which is consistent with Supplementary Information Section V.C. "Corrective Actions and Reporting Requirements."

Basis of proposal: First principles and engineering judgment are appropriate for use in determining the effect of a change or an error.

Comment #10: Page 16142, 50.46c(m)(3) Breakaway oxidation

Statement in Rule: "(3) *Breakaway oxidation.* Each holder of an operating license or combined license shall measure breakaway oxidation for each reload batch. The holder must report the results to the NRC annually (i.e., anytime within each calendar year), in accordance with § 50.4 or § 52.3 of this chapter, and evaluate the results to determine if there is a failure to conform or a defect that must be reported in accordance with the requirements of 10 CFR part 21."

Description of Concern: The term "holder of an operating license" implies that the licensee will be performing the testing. Annual and reload batch reporting is inappropriate. The testing result is being reported on rather than the ECCS evaluation result.

Basis for concern: See AREVA Response to NRC Question (2) and AREVA DG-1261 Comment #1. The cladding manufacturer will be responsible for the testing. The testing result only establishes the criteria to which an ECCS evaluation result is compared. Consistent with the other reporting, the only value that should be reported on is changes to the LOCA analysis result.

Proposal: A record of the testing results would be maintained by the cladding manufacturer and be available for audit, see AREVA DG-1261 Comment #3. The only breakaway oxidation reporting by a licensee should be relative to changes in the time-at-temperature analytical result or changes in the established analytical limit used in that analysis. Note: The established analytical limit is not necessarily the minimum time to breakaway oxidation or the periodic testing time (See also AREVA DG-1261 Comment #4). 50.46c(m)(3) could be removed.

Basis of proposal: n/a

Comment #11: Page 16113, Supplementary Information Section A. Applicability of Performance-Based Rule: Consideration of PRM-50-71

Statement in DG: The AREVA cladding M5® is referred to as simply M5

Description of Concern: M5 is a registered trademark of AREVA and should always be represented as M5®.

Basis for concern: n/a

Proposal: Modify FRN to use M5® and include a footnote at the end of the main document as "M5® is a registered trademark of AREVA NP."

Basis of proposal: n/a

Enclosure 2

AREVA Response to Proposed 10 CFR 50.46c Supplementary Information Section VII Selected Questions

NRC Question 1. ***Performance-Based Peak Cladding Temperature Limit***

The NRC is proposing, in § 50.46c(g)(1)(i), to maintain the existing prescriptive criterion on PCT for zirconium alloy cladding. Limits on cladding temperature are necessary to protect against a loss of coolable geometry resulting from brittle failure upon quench, to protect against high temperature ductile failure, and to prevent reaching the point at which the zirconium-water reaction would become autocatalytic. In the original § 50.46 rulemaking, the 2200 °F limit on PCT was based on cladding embrittlement (i.e., protection against brittle failure upon quench), which was determined to be more limiting than either high temperature ductile failure or autocatalytic oxidation. The NRC's LOCA research program did not investigate cladding degradation mechanisms or develop the technical basis for performance-based requirements beyond the existing 2200 °F PCT criterion. Since the cladding embrittlement mechanism, oxygen diffusion, is strongly dependent on temperature, there exists an upper temperature at which the allowable time duration to nil ductility approaches zero (i.e., PCT °limit). As described in Section V.B.1 of this document, recent research has confirmed that 2200 °F remains an appropriate upper limit to protect against cladding embrittlement since nil ductility is achieved rapidly at higher temperature. As such, the proposed § 50.46c maintains the 2200 °F prescriptive PCT criterion.

The NRC requests comment on the proposed rule's retention of the prescriptive PCT criterion, specifically:

a. In place of the prescriptive PCT criterion, should the NRC adopt performance-based requirements for zirconium alloy cladding to protect against high temperature ductile failure and autocatalytic oxidation?

b. Do established testing procedures already exist for demonstrating acceptable high temperature cladding performance and defining acceptance criteria to meet these new performance-based requirements?

Response to NRC Question 1:

AREVA supports removing the PCT limit from the rule itself and placing it in DG-1263 as the current maximum oxidation temperature and thus the limit on PCT. In moving the 2200°F limit to DG-1263, language in DG-1263 will need to be added relative to other considerations that may degrade the fuel and need additional testing beyond PQD testing. AREVA Rule Comment #6 also addresses this issue.

NRC Question 2. *Periodic Breakaway Testing.*

To address the breakaway oxidation phenomenon, the NRC proposes to add a performance-based requirement in § 50.46c(m)(3) that the licensee measure the onset of breakaway oxidation periodically on manufactured cladding material and report any changes in the onset of breakaway oxidation at least annually. This requirement, along with a periodic test requirement (defined as each reload batch in the proposed rule language), would confirm that slight composition changes or manufacturing changes have not inadvertently altered the cladding's susceptibility to breakaway oxidation. The NRC is considering adopting, as a final rule, a requirement that each licensee measure breakaway oxidation behavior for each re-load batch. The NRC requests specific comment on the type of data reported and the proposed frequency of required testing. The objective of periodic testing is to prevent affected fuel from being loaded into a reactor. At the same time, the objective is to do so without adding ineffective requirements and unnecessary burden. Other sampling approaches may be more effective. For example, should the licensee be required to report data relevant solely to their reload fuel batch or should the licensee be able to report representative data based on periodic testing (e.g., test every 10,000 rods, tubing lot, or ingot) of the same zirconium-based alloy cladding compiled during the period from the last report?

Response to NRC Question 2:

To provide reasonable assurance that cladding used in a plant will not be susceptible to breakaway oxidation, the testing requirements should be established to demonstrate that the manufacturing process itself produces cladding consistent with the established limit. More details and justification for this proposal are provided in AREVA DG-1261 Comments #1 and 4. It is proposed that a periodic test program be developed by each vendor and approved by the NRC. The program would include details relative to the frequency of the tests, which would be specific to each vendor's process, and record keeping or reporting that demonstrate that the cladding behavior relative to breakaway oxidation remains unchanged. Therefore, the only licensee responsibility would be to verify that the plant specific LOCA analysis demonstrates time-at-temperatures that are below the established analytical limit for the cladding used. Changes in the analytical limit or LOCA analysis result would be reported consistent with the other short term LOCA criteria.

Additionally, it is suggested that those fuel assemblies with cladding manufactured prior to the implementation of the new rule be grandfathered. The lead time associated with the preparation and delivery of a fuel assembly reload batch would essentially require the testing to be in place today. Acceptable test programs still need to be created and reviewed by the NRC. Since the draft regulatory guidance will not become final until the time of rule publication, it is not feasible to begin the testing now. Furthermore, in order to develop an acceptable test program, it is requested that updated drafts of DG-1261 be made available as soon as reasonably possible. The time required to establish these programs at the vendor facilities cannot wait until the rule publication.

NRC Question 3. *Analytical Long-Term Peak Cladding Temperature Limit.*

Section 50.46c(g)(1)(v) of the proposed rule would require that a specified and NRC-approved limit on long-term peak cladding temperature be established which preserves a measure of cladding ductility throughout the period of long-term demonstration (e.g., 30 days). The current regulation at § 50.46(b)(5) stipulates that long-term temperature be maintained "at an acceptably low value." The proposed rule would define the performance-based metric to judge an acceptably low temperature. The overall goal of preserving ductility would provide reasonable assurance that the fuel rods will maintain their coolable bundle array. The NRC is requesting input regarding this performance objective to determine if this is the most suitable performance-based metric to demonstrate long-term cladding performance.

Alternatively, the proposed rule could establish an analytical limit of long-term fuel rod cladding temperature related to observed corrosion behavior. For example, the Pressurized Water Reactor Owners Group (PWROG) has applied as a long-term core cooling acceptance criterion that the cladding temperature be maintained below 800 °F (see Topical Report (TR) Westinghouse Commercial Atomic Power (WCAP)-16793-NP, Revision 2, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid," Appendix A (ADAMS Accession No. ML11292A021)). Doing so will ensure that additional corrosion and hydrogen pickup over a 30-day period will not significantly affect cladding properties. The NRC seeks comment on the acceptance criterion for long-term cooling and whether there is justification for a different temperature limit (other than the 800 °F provided in the WCAP).

Response to NRC Question 3:

A single peak cladding temperature is not appropriate as a limit for the long-term cooling ductile-to-brittle transition or any potential additional degradation mechanisms possible in the long-term. There are operational and design considerations involved with some plants of the current U.S. fleet that may require a temperature envelope. The NRC should conduct stakeholders meetings to establish a limit on long-term cooling cladding degradation. AREVA Rule Comment #7 also addresses this issue.

NRC Question 11. ***Re-structuring 10 CFR Chapter I with respect to ECCS Regulations.***

The NRC is considering restructuring its ECCS regulations as part of the finalization of this rulemaking due to: 1) Commission direction to include in the proposed rule a provision allowing licensees to use a risk-informed submittal to address the effects of debris during the long-term recovery period; and 2) the potential benefit and efficiency of collocating all ECCS-related requirements within the CFR. As such, the NRC seeks comment on the following potential administrative changes:

- *Codify the performance-based ECCS and cladding requirements (as proposed in this document) as a new section, § 50.181.*
- *Reserve § 50.183 for the potential future risk-informed ECCS requirements rule (currently referred to as the draft final § 50.46a rule).*
- *Codify the requirements for the risk- informed submittals (proposed as § 50.46c(e) in this proposed rule) to address the effects of debris in the long-term recovery period as a new section, § 50.185.*
- *Duplicate the content of appendix K to 10 CFR part 50, ECCS evaluation models, and add the content as a new section, § 50.187. (The NRC notes that appendix K to 10 CFR part 50 will remain in place until all licensees have implemented the proposed requirements (i.e., until completion of the proposed staged implementation period).)*
- *If this restructure is pursued, following the completion of the proposed staged implementation period, the NRC would make the following administrative changes:*
    - *Remove the current § 50.46, ECCS acceptance criteria, in its entirety.*
    - *Remove the current appendix K to 10 CFR part 50, in its entirety. (The content will exist as § 50.187.)*
    - *Redesignate the current § 50.46a, "Acceptance criteria for reactor coolant system venting systems," as § 50.46.*

The tables that follow depict the described potential changes:

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Should this restructure be pursued, the following table depicts the structure of 10 CFR part 50 after finalization of the § 50.46a Risk-Informed ECCS Requirements and after the proposed staged implementation of the § 50.46c Performance-based ECCS and Cladding Requirements rulemaking is complete:

<Table not reproduced>

The NRC acknowledges that such changes could have a large impact on licensees and vendors with regard to procedures, plans, programs, topical reports, and engineering calculations that reference appendix K to 10 CFR part 50 and the current ECCS regulations. In your comments, please include the estimated cost for conforming changes to topical reports, licensing amendments, and other technical documents. Please also comment on whether the anticipated benefits and efficiencies would outweigh the administrative burden, costs, and complexities.

Response to NRC Question 11:

The current regulation structure of 10 CFR 50.46 and 10 CFR 50 Appendix K is deeply engrained in all aspects of AREVA LOCA methods, procedures, processes, and culture. AREVA believes that identifying all locations in all topical reports, procedures, and processes, as well as computer codes and peripheral documentation that would require modification if the

regulation were restructured is an unwarranted and costly task that would not improve safety. AREVA, therefore, recommends against a restructuring of the regulation.

Enclosure 3

AREVA Comments on Draft Regulatory Guide 1261

Comment #1: Section B, "Periodic Testing"; Appendix A, Page A-3.2

Statement in DG: The Draft Regulatory Guide states "Specifically, it is acceptable to measure the onset of breakaway oxidation annually for each reload batch [emphasis added] for only the temperature at which the minimum time to breakaway oxidation was measured and to demonstrate that breakaway oxidation is not experienced within the time of the established analytical limit."

Description of Concern: DG-1261 and the rule specify testing every reload batch.

Basis for concern: Testing for every reload batch is not consistent with the cladding manufacturing process and the NRC position to "confirm that slight composition changes or manufacturing changes have not inadvertently altered the cladding's susceptibility to breakaway oxidation."

Proposal: Replace wording with the following: "The cladding shall be tested for susceptibility to breakaway oxidation in order to establish an analytical limit to be used in the LOCA analysis. A periodic test program should be devised to demonstrate that the manufacturing process continues to produce cladding that supports the established analytical time limit. This test program is to be reviewed and found acceptable by the NRC."

Basis of proposal: The industry-wide testing has demonstrated that the breakaway oxidation phenomenon is attributed to various stages in the manufacturing process. As such, the testing requirements should be established to demonstrate that the manufacturing process itself produces cladding consistent with the established limit. Each vendor would submit their own breakaway oxidation testing program. Details such as the frequency of the tests would be included within that program to be approved by the NRC.

It is not known a priori which cladding tubes will be used in which plant's reload batch. Additionally, a reload batch of fuel assemblies can include several different batches of cladding tubes, so the "reload batch" testing would not necessary envelope the concern. By qualifying the manufacturing process, any susceptible cladding tubes would be identified early enough in the process for the vendor to take additional actions. In this way, susceptible cladding would never be delivered to a utility. Utilities then only need to reference a qualified vendor program for their reload batch and the requirement for annual reporting is eliminated.

Comment #2: General comment

Statement in DG: Draft Regulatory Guide-1261 uses the phrase "analytical limit" relative to the periodic testing throughout.

Description of Concern: DG-1261 should only describe the testing protocol for breakaway oxidation. DG-1263 should establish the analytical time limit based on the results of the testing.

Basis for concern: The terminology will likely lead to confusion and misinterpretation.

Proposal: Use a different phrase to distinguish between the time used for the periodic testing and the time used to evaluate the small break LOCA analysis (e.g. "periodic testing breakaway oxidation time" and "analytical time limit").

Basis of proposal: The time for periodic testing may not be the same time used in evaluating the small break LOCA analysis results. The time used in the SBLOCA, the "analytical limit," may include conservatism. DG-1263 states that the testing is only used to establish an analytical limit that is "less than or equal to the shortest time observed to lead to breakaway oxidation" (DG-1263 Section C, Regulatory Position #5); therefore, the testing time in DG-1261 should not be referred to as "established analytical limit."

Comment # 3: Section B, "Periodic Testing"; Appendix A, Page A-3.2; Appendix E

Statement in DG: As an example, the Draft Regulatory Guide States "Specifically, it is acceptable to measure the onset of breakaway oxidation [emphasis added] for each reload batch for only the temperature at which the minimum time to breakaway oxidation was measured and to demonstrate that breakaway oxidation is not experienced within the time of the established analytical limit."

Description of Concern: The phrase indicates that the exact timing for breakaway oxidation must continually be determined. Reporting changes to and continuously testing for the onset of breakaway oxidation is overly burdensome. The phrase appears in various contexts throughout the guide.

Basis for concern: To measure the exact onset of breakaway oxidation would be a very arduous process requiring the initial scoping matrix to be repeated in the periodic testing phase. It is inconsistent with the second part of the sentence that it be demonstrated that breakaway oxidation is not experienced within a pre-set time. Knowing the exact time has little value in demonstrating the susceptibility of a plant design to breakaway oxidation.

Proposal: The "onset of breakaway oxidation" statements should be modified as appropriate throughout the Regulatory Guide.

Basis for Proposal: The onset of breakaway oxidation is not necessary for the continued demonstration that a previously determined limit for breakaway oxidation is not challenged. Additionally, NUREG/CR-6967 has demonstrated that there is inherent variability in the precise timing. The Guide should allow the periodic tests to be performed up to a time less than the minimum breakaway oxidation time (or 5,000 seconds). For example, if 4,200 seconds has been determined in the initial scoping tests as the minimum time for the onset of breakaway oxidation, a vendor may only wish to test the cladding for 4,000 seconds. In such a scenario, the product's time limit would be no greater than 4,000 seconds. The analytical limit can be established at or below that time (for the example, at or less than 4000 seconds).

Comment # 4: Section B, "Periodic Testing"; Appendix A, Page A-3.2; Appendix E

Statement in DG: In the *"Reporting Results of Periodic Testing"* section, the Draft Regulatory Guide states "it is acceptable to report only changes in the time to the onset of breakaway oxidation."

Description of Concern: The time for the onset of breakaway oxidation is not a result of the periodic testing. Reporting changes to and testing of the minimum breakaway time is overly burdensome.

Basis for concern: As stated in the Draft Regulatory Guide, the intent of the periodic testing is to demonstrate that breakaway oxidation is not experienced within the time of the established analytical limit, but the reporting requirement is inconsistent with this.

Proposal: The *"Reporting Results of Periodic Testing"* section should be removed or modified to state "a record of the testing should be maintained by the testing organization and available for NRC audit. It is acceptable to report only test results that affect the established analytical limit for breakaway oxidation."

Basis for Proposal: The testing would be done by the vendor at the cladding manufacturing stage, prior to fuel assembly reload batch delivery and the requirement for reporting of the test result can be removed. Therefore, consistent with the other 10 CFR 50.46c criteria, the only reporting metric for the plant should be relative to a change in the plant's SBLOCA analysis time-at-temperature result. However, if reporting on the periodic test results is still desired, it should reflect the results of the periodic tests as opposed to the onset of breakaway oxidation time, which is not measured through the periodic testing.

Comment #5: Section B, "Periodic Testing"; Appendix A, Page A-3.2; Appendix E

Statement in DG: An example from Section B of the Draft Regulatory Guide states "Specifically, it is acceptable to measure the onset of breakaway oxidation for each reload batch for only the temperature at which the minimum time to breakaway oxidation was measured [emphasis added] and to demonstrate that breakaway oxidation is not experienced within the time of the established analytical limit."

Description of Concern: Two scenarios are possible from the initial scoping test. In one scenario, there is a temperature that corresponds to a minimum time to breakaway oxidation. In the other, there are no temperatures that demonstrated breakaway oxidation before 5,000 seconds. In the second scenario, a temperature cannot be associated with a minimum time and a default of 1000°C is implied by the guide (but not clear, see AREVA DG-1261, Comment #16). There are several places in DG-1261 where only "the temperature at which the minimum time..." is used.

Basis for concern: Some of the wording in DG-1261 is inconsistent with a scenario allowable by the Guideline.

Proposal: Modify DG-1261 to resolve discrepancy. For example, the phrase could be modified to "the temperature at which the minimum time to breakaway oxidation was measured or at 1000°C, if all temperatures show no breakaway oxidation by 5,000 seconds."

Basis of proposal: n/a

Comment #6: General comment

Statement in DG: The Draft Regulatory Guide states "If no documentation is provided, then the scratch should extend along the length of the sample and have a depth of 50±5 μm and a width of 50±5 μm, defined as bounding based on metallographic observations made of scratches induced by repeated insertion of fuel rod cladding into and out of grid spacers." The Draft Regulatory Guide prescribes testing with this scratch and states that "If it has been shown that scratches and post polishing cleaning have an insignificant effect (i.e., results within data scatter) on the minimum breakaway oxidation time, then as-manufactured cladding may be used for periodic testing."

Description of Concern: A heavy emphasis is placed on the quantification of the scratch impact. The scratch dimensions, in particular the tolerance, are overly restrictive. The Guide only allows testing as-manufactured cladding if the scratch has an insignificant (i.e., results within data scatter) effect.

Basis for concern: Scratches have a low-level effect on the breakaway oxidation phenomenon (NUREG/CR-6967 concluded that there was ≈200 second effect of a design-basis scratch). The prescriptions in the DG-1261 scratch testing though are very restrictive.

- The 5 μm tolerance is not reasonably achievable.
- Testing with a scratch in the periodic phase is burdensome, but the only way to use as-manufactured cladding in the periodic testing phase is if the scratch has an insignificant effect. The term "insignificant" is subject to interpretation.
- Documentation on scratches is not readily available.

Proposal: As a low level effect, the scratch should be treated in a more realistic manner. The 5 μm tolerance requirement should be removed or relaxed. A more reasonable and achievable tolerance is 10 -15 μm.

As-manufactured cladding should be allowed in the periodic testing phase as long as the limit accounts for the impact determined in the initial scoping tests (See "Basis of proposal").

The details on the initial scoping test scratch and the manner in which to account for it in the periodic testing would be included with the vendor's testing program to be approved by the NRC, but the Regulatory Guide should allow it to be considered implicitly in the limit or explicitly in the periodic test.

If the proposal is not accepted, the term "insignificant" should be more clearly defined in DG-1261 since the initial scoping tests will not produce sufficient information to categorize "data scatter."

Basis of proposal: Testing of a bounding scratch with tight tolerance and on a periodic basis is not reasonable given the low-level effect identified in NUREG/CR-6967, "Cladding Embrittlement during Postulated Loss-of-Coolant Accidents," July 2008. Additionally, scratch testing in the periodic phase is overly burdensome. In NUREG/CR-6967, an approximate time impact was determined and applied to the onset of breakaway oxidation time. In a similar manner, the time impact as determined in the initial scoping tests could be used in conjunction with the results from the periodic testing phase in order to use as-manufactured cladding in the periodic tests.

Comment #7: Appendix A, Pages A-5.2, A-5.3, A-5.4, A-5.5

Statement in DG: The Draft Regulatory Guide lists certain heating methods as "not recommended"

Description of Concern: The NRC concern is more generically associated with temperature control, as opposed to specific heating methods. A method that is "not recommended" can be easily interpreted as "not allowed."

Basis for concern: As long as adequate temperature measurement and control (e.g., ramp rates) can be attained and the breakaway oxidation phenomenon is not affected by the method, the method of heating need not be specified. Previous challenges or preconceptions about the heating methods should not carry forward as prescriptions in regulatory guidance. Regardless of the heating methods, all must show thermal benchmarks

Proposal: Recommendations for specific heating methods should be removed. Section A-5.2, A-5.3, A-5.4, A-5.5 can be replaced with a single section focusing on adequate temperature control or the ability of a certain heating method to demonstrate breakaway oxidation results similar to those published in NUREG/CR-6967 (See AREVA DG-1261, Comment #9).

Basis of proposal: As an example of a "not recommended" method that has demonstrated the acceptable application to breakaway oxidation: The paper by V. Vandenberghe et al. "Sensitivity to Chemical Composition Variations and Heating/Oxidation Mode of the Breakaway Oxidation in M5 Cladding Steam Oxidized at 1000°C (LOCA conditions)," presented at LWRFPM, Manchester, UK, 2012 concluded that "No significant impact of the heating mode was observed on the breakaway incubation time, on pre-and post breakaway alpha (O) layer thickness or on oxidation kinetics or H pick up in post breakaway regimen."

Comment #8: Appendix A, Page A-6.3

Statement in DG: The Draft Regulatory Guide states that "After thermal benchmarking, samples should be tested without TCs welded onto the sample to determine the weight gain." The results of those tests are to be used in weight-gain benchmarks.

Description of Concern: There are several statements within this section that pose challenges to testing. The value of the weight-gain benchmark is unclear. AREVA believes it is intended as a benchmark of the temperature control process.

Basis for concern: For the weight-gain benchmark, there are two temperatures required, one at 800°C and one at 1000°C. The 1000°C benchmark is done for 2000 seconds and for Zr-2, Zr-4, or ZIRLO must be within 10% of Cathcart-Pawel (CP) correlation to proceed with testing. For other materials and for the 800°C benchmark, a well-established vendor database is to be used. Most alloys at 2000 seconds are in fact below 90% of CP. The databases that vendors do have are limited.

Proposal: The thermocouple calibration and temperature benchmark should be sufficient and the weight-gain benchmark could be removed. If, however, a weight-gain benchmark is necessary, the Guide should be more flexible in the prescriptions. Only one test temperature should be required. The test temperature and time should also be more flexible to allow for closer benchmark results. The CP correlation will benchmark better at higher temperatures and shorter times.

Basis of proposal: n/a

Comment #9: General Comment

Statement in DG: n/a

Description of Concern: The DG does not ensure that the testing protocol is capable of producing breakaway oxidation.

Basis for concern: Without a demonstration that the testing protocol can produce breakaway oxidation, false positives or unrealistically long times to breakaway oxidation could result. Some laboratories in the round-robin testing (Yueh, H.K., et. al "Loss of Coolant Accident Testing Round Robin" *LWR Fuel Performance Meeting TopFuel 2013*) did not achieve breakaway oxidation.

Proposal: A single test using the vendor's testing protocol should be performed on a material tested previously (DG-1261 Table 1, NUREG/CR-6967) to qualify the vendor's testing devices and specifications. The time for which breakaway occurs with the current protocol would be compared to the published time (or, for the case when no breakaway was seen by 5,000 seconds, to the time achieved with the methods used therein). Given the degree of variability and unknowns about the published tests, there should not be a ±% specified, but rather a demonstration of reasonableness.

Basis of proposal: A demonstration of the testing technique to produce breakaway oxidation is perhaps more important than benchmarks and would allow for some requirements and restrictions that were added for uncertainty (e.g., heating method, optical pyrometry, maximum steam flow rate) to be removed.

Comment #10: Appendix A, Page A-7.1

Statement in DG: The Draft Regulatory Guide states "ASTM G2/G2M–06 (Ref. 7) specifies that Grade A water with ≤45 parts per billion of oxygen should be used for corrosion tests in pressurized water and steam."

Description of Concern: The 45 ppb oxygen content is difficult to achieve and not reasonable for application.

Basis for concern: In a LOCA event, the water will not be from an oxygen controlled source. The low level of oxygen could actually be non-conservative with respect to breakaway oxidation. The 45 ppb requirement could also be misinterpreted as applying to Type I water.

Proposal: Remove the oxygen content requirement.

Basis of proposal: n/a

Comment #11: Appendix A, Page A-7.2

Statement in DG: The Draft Regulatory Guide states "The average steamflow rate should be in the range of 0.5 to 30 mg/square centimeter per second ($cm^2 \cdot s$)."

Description of Concern: The DG states that "it is not clear why higher steamflow rates would have an effect on weight gain and oxidation kinetics." It follows by stating that "Although the maximum steamflow rate may not be as critical as the minimum steamflow rate, it should be limited to ≤30 mg/($cm^2 \cdot s$) for the purposes of breakaway oxidation tests."

Basis for concern: There should not be a restriction without a technical justification. This may limit current and future testing techniques.

Proposal: Remove the upper limit on steam flow rate.

Basis of proposal: A qualification of the testing technique would be sufficient. See Comment #9.

Comment #12: Appendix A, Page A-8.4

Statement in DG: The Draft Regulatory Guide states "After the target test time has been reached, furnace power should be turned off while steam flow is maintained. The rate of temperature decrease will depend on the heating method used and the method of removing the sample from the furnace. For in situ cooling, the steam flow should be maintained until the sample temperature reaches 800 °C."

Description of Concern: The section is overly prescriptive and not technically justified.

Basis for concern: Unless the cooldown would non-conservatively affect the breakaway oxidation result, the requirement is unnecessary. The at-temperature test goal has been achieved and a slower cooldown would increase the high temperature oxidation. The requirement for slow cooldown to 800°C could preclude certain methods, such as direct quench.

Proposal: Remove the cooldown prescription.

Basis of proposal: n/a

Comment #13: Appendix A, Pages A-9.4, A-9.5

Statement in DG: The Draft Regulatory Guide states "The average minus-one standard deviation should be compared to the 200-wppm hydrogen pickup to determine if breakaway has occurred" (A-9.4) and "The 200-wppm -hydrogen breakaway criterion is reasonable and justified at the higher oxidation temperatures at which the minimum breakaway oxidation time is most likely to occur." (A-9.5)

Description of Concern: The DG does not specify if 200-wppm H pick-up is relative to one-sided or two-sided oxidation tests.

Basis for concern: There is a factor of two between the two types of tests.

Proposal: Specify 200-wppm for one-sided tests, 400-wppm for two-sided tests. This should be clarified throughout the Guide.

Basis of proposal: n/a

Comment #14: Appendix A, Page A-9.4

Statement in DG: The Draft Regulatory Guide states "The average minus-one standard deviation [emphasis added] should be compared to the 200-wppm hydrogen pickup to determine if breakaway has occurred"

Description of Concern: The application of the standard deviation to the result is not appropriate.

Basis for concern: The smaller the sample size, the larger the standard deviation. For the requested test, there are only five samples. As such, using the standard deviation is overly conservative. However, if the standard deviation is required, it should be added to the average in order to compare to a less-than 200-wppm limit.

Proposal: Remove the standard deviation from the comparison: "The average should be compared to the 200-wppm hydrogen pickup to determine if breakaway has occurred"

If the application of the standard deviation is required, it should be added: "The average plus-one standard deviation should be compared to the 200-wppm hydrogen pickup to determine if breakaway has occurred"

Basis of proposal: n/a

Comment #15: Appendix A, Page A-9.6

Statement in DG: Entire Text in Section A-9.6

Description of Concern: The recommendations in this section are not clear.

Basis for concern: The section seems to be a discussion about potential aspects of the different test approaches. It is not clear if the additional testing is required to use either method or what the staff is recommending. Hydrogen losses to the end caps should be covered by the sample length section (A-4.2).

Proposal: Remove this section or clarify the intent and recommendations for the two types of tests.

Basis of proposal: n/a

Comment #16: Appendix A, Page A-10 and Appendix E

Statement in DG: n/a

Description of Concern: The words in Appendix E are not clear about the matrix of tests for repeatability and scratch testing. The words for periodic testing only described the scenario when a minimum time-temperature combination is determined.

Basis for concern: In particular, for the scenario when no minimum time-temperature is determined, the protocol is confusing and could lead to misinterpretation.

Proposal: Clarify the wording with a table of the tests required for repeatability and scratch testing. Each scenario (Scenario #1: minimum time-temperature combination established; Scenario #2: no minimum time-temperature combination) should be identified with its own matrix of tests with the temperature for each test in the matrix identified. The periodic testing words and schematic should allow for Scenario #2.

Basis of proposal: n/a

Comment #17: General comment

Statement in DG: The AREVA cladding M5® is referred to as simply M5 throughout the guide.

Description of Concern: M5 is a registered trademark of AREVA and should always be represented as M5®.

Basis for concern: n/a

Proposal: Modify DG-1261 to use M5® and include a footnote at the end of the main document as "M5® is a registered trademark of AREVA NP."

Basis of proposal: n/a

Enclosure 4

AREVA Comments on Draft Regulatory Guide 1262

Comment #1: Page 12, Sections 5.4 and 5.5

Statement in DG: "With proper thermal benchmarking, induction-heating furnaces might be acceptable for generating PQD samples. However, as it is not clear how to do the benchmarking, the use of induction heating is not recommended for preparing PQD samples."

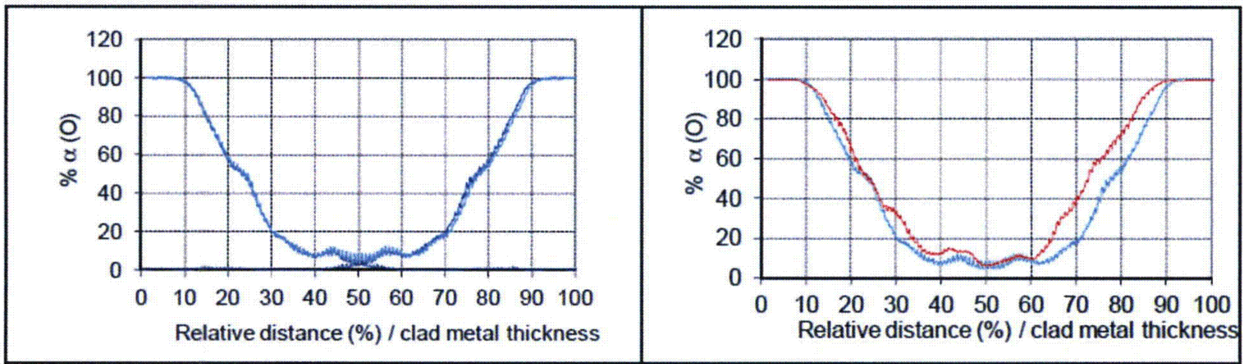
"Because resistance and heating rate change with temperature, direct electrical heating of cladding is not recommended for preparing PQD samples."

Description of Concern: The proper concern is with temperature control, as opposed to specific heating methods. A method that is "not recommended" can be easily interpreted as "not allowed."

Basis for concern: As long as adequate temperature measurement and control (e.g., ramp rates) can be attained and postquench ductility is not affected by the method, the method of heating need not be specified. Previous challenges or preconceptions about the heating methods should not carry forward as prescriptions in regulatory guidance. Regardless of the heating methods, all must show thermal benchmarks.

Proposal: Recommendations for specific heating methods should be removed. Section 5.2 through 5.5 can be replaced with a single section focusing on adequate temperature control or the ability of a certain heating method to demonstrate results similar to those that are generally accepted.

Basis of proposal: Broad guidance on heating methods will encourage the development of better techniques. Furthermore, the paper, V. Vandenberghe *et al.* "Sensitivity to Chemical Composition Variations and Heating/Oxidation Mode of the Breakaway Oxidation in M5 Cladding Steam Oxidized at 1000°C (LOCA conditions)," presented at LWRFPM, Manchester, UK, 2012 showed that the oxygen profiles were nearly identical between CINOG (induction heating) and DEZIROX (radiation heating) (see figure below). Since, for a given material and pre-hydrogen content, post-quench behavior is directly related to the prior-β thickness and oxygen content, induction heating will not impact PQD behavior.



(c) (d)

Fig 5. Comparison of the α(O) layer obtained after 3270s at 1000°C in SS-FH or DS-IH conditions; (a) SEM images; (b) % α(O) layer deduced from SEM images analysis; (c) projected DS-FH α(O) layer distribution; (d) comparison between measured DS-IH and projected DS-FH

Comment #2: Page 13, Section 6.2

Statement in DG: Entire section

Description of Concern: The description of the thermal benchmark discusses only radiant and resistance heating devices.

Basis for concern: Other heating methods, such as direct electrical and induction heating, are not properly addressed.

Proposal: The Regulatory Guide should provide criteria that are independent of the heating method.

Basis of proposal: Guidance should be as broadly applicable as is practical to allow for the use of any appropriately qualified heating method. See

Comment **#1**.

Comment #3: Page 14, Section 6.3

Statement in DG: The section states that "Following thermal benchmarking, samples should be tested without TCs welded onto the sample to determine the weight gain. These tests should be conducted at 1,200 °C, 1,100 °C, and 1,000 °C for a test time corresponding to 10% CP-ECR." It goes on to state, "the weight gain for a particular cladding material should deviate by less than 10% from the vendor-established database for that material before the start of data-generating tests."

Description of Concern: There are several statements within this section that pose challenges to testing.

Basis for concern: The vendor database may not have been developed in accordance with the regulatory guide, so it is not clear that the test results should agree with the database. Three weight-gain benchmarks are specified.

Proposal: The thermocouple calibration and temperature benchmark should be sufficient and the weight-gain benchmark could be removed. However, if a weight-gain benchmark is necessary, the Guide should be more flexible in the prescriptions. Only one temperature benchmark is necessary to independently validate the thermal benchmark.

Basis of proposal: Since the vendor database is not generated in the same manner as DG-1262 prescribes, the tolerance on the comparison is too stringent. Also, it is stated that the weight-gain benchmark is a supplement to the thermal benchmark. Therefore, if a weight-gain benchmark is absolutely necessary, a single test temperature would be sufficient to validate the thermal benchmark conclusion.

Comment #4: Page 15, Section 7.1

Statement in DG: "Grade A water with ≤45 parts per billion (ppb) oxygen should be used for corrosion tests in pressurized water and steam"

Description of Concern: The 45 ppb oxygen content is difficult to achieve and not reasonable for application.

Basis for concern: In a LOCA event, the water will not be from an oxygen controlled source. The low level of oxygen could actually be nonconservative. The 45 ppb requirement could also be misinterpreted as applying to Type I water.

Proposal: Remove the oxygen content requirement.

Basis of proposal: n/a

Comment #5: Page 15, Section 7.2

Statement in DG: "The average steamflow rate should be in the range of 0.8 to 30 mg/square centimeter (cm^2) s)."

Description of Concern: The DG states that "it is not clear why higher steamflow rates would have an effect on weight gain and oxidation kinetics." It follows by stating that "Although the maximum steamflow rate may not be as critical as the minimum steamflow rate, it should be limited to ≤ 30 mg/($cm^2 \cdot s$)."

Basis for concern: There should not be a restriction without a technical justification. This may limit current and future testing techniques.

Proposal: Remove the upper limit on steam flow rate.

Basis of proposal: A qualification of the testing technique would be sufficient.

Comment #6: Page 16, Section 8.2

Statement in DG: "Following introduction of steam into the chamber, furnace heating should commence for a pretest hold temperature of 300 °C. Stabilization of steamflow and 300 °C sample temperature should occur within 500 seconds."

Description of Concern: It is not clear why the specified temperature and time were chosen.

Basis for concern: Without a basis for the pretest hold temperature and time, it will be difficult to evaluate any deviations. Alternate temperatures may be desired.

Proposal: Allow flexibility on pretest hold temperature or provide a basis for the stabilization temperature and time.

Basis for Proposal: n/a

Comment #7: Page 17, Section 9.2

Statement in DG: "The posttest sample weight should be measured to the nearest 0.1 mg as specified in 7.1.3 of EP-Ref. 7. The weight gain (in mg) is determined by subtracting the pretest weight from the posttest weight and normalizing this value to the steam-exposed surface area of the sample. Although this normalized weight gain is not used to determine the oxidation level, it is used to validate temperature control and monitoring, as well as adequacy of steamflow and test procedures throughout the data-generating phase of testing."

Description of Concern: The guide does not describe how to handle samples with oxide spallation.

Basis for concern: If oxide spalls, the weight gain might not be as expected, and the sample might be considered invalid.

Proposal: Allow the investigator to disregard weight gain measurements if oxide spalls.

Basis for Proposal: n/a

Comment #8: Page 18, Section 10.2

Statement in DG: "For tests with prehydrided cladding, the hydrogen contents selected should be in a range relevant to the cladding material"

...

"Hydrogen levels used in PQD testing with prehydrided cladding materials should cover the anticipated range of hydrogen in the metal of irradiated cladding."

Description of Concern: The phrases "range relevant" and "anticipated range" are not clearly defined.

Basis for concern: The relevant or anticipated range may be defined differently for different materials.

Proposal: The phrases "be in a range relevant to the cladding material" and "cover the anticipated range of hydrogen in the metal of irradiated cladding," should be replaced with "extend to the best-estimate hydrogen concentration at maximum burnup."

Basis of proposal: n/a

Comment #9: Section 10.2

Statement in DG: This section of DG-1262 provides guidance on the testing required to support a given PQD Limit curve.

Description of Concern: The testing to confirm a PQD limit curve is presented in DG-1263 and the discussion in this section is somewhat contradictory to that presented in DG-1263. DG-1262 and 1263 should not present the same material, or if they do, they should not contradict each other.

Basis for concern: Multiple contradictory statements on tests to support a specific PQD limit curve.

Proposal: Present required testing in either DG-1262 or 1263. Remove the corresponding sections in the other document or make the requirements similar in both documents.

Basis of proposal: n/a

Comment #10: Page 19, Section 10.2

Statement in DG: In addition to comment #9, as a detail DG-1262 states "...three tests should be conducted at the intermediate CP-ECR to confirm the embrittlement threshold."

Description of Concern: The three tests may give different results, and it is not clear how to interpret that outcome.

Basis for concern: Variation in results is normal and expected.

Proposal: Provide additional guidance on how to interpret the data if different samples give different results. For clarity, mention interpolation and provide a cross reference to Section 12.2.

Basis of proposal: n/a

Comment #11: Page 22, Section 12.2

Statement in DG: "the CP-ECR [for the ductile-brittle transition] may be determined from interpolation between an oxidation level for which the permanent strain is >1.0% (ductile) and an oxidation level for which the permanent strain is <1.0%. ... For example, if the sample is ductile at 8% CP-ECR and brittle at 10% CP-ECR and no further testing is conducted, the transition CP-ECR would be reported as 8%."

Description of Concern: The guidance allows interpolation, but the example does not include interpolation.

Basis for concern: The discussion of interpolation is inconsistent with the example.

Proposal: Delete the example or replace it with a more detailed example that reports strains and then interpolates. Make the interpolation procedure consistent between DG-1262 and DG-1263. See AREVA DG-1263 Comment #4.

Basis of proposal: n/a

Comment #12: Page 22, Section 12.2

Statement in DG: "Based on multiple oxidation tests in a narrow range and multiple ring-compression samples, the permanent strains were 1.5±0.4% at 15.2% CP-ECR and 1.1±0.3% at 16% CP-ECR, where the ± values represent one standard deviation caused by data scatter from repeat tests. Based on linear extrapolation, the transition CP-ECR is calculated to be 16%."

Description of Concern: The method for the extrapolation is not entirely clear.

Basis for concern: The method may be interpreted as an extrapolation on mean values; or alternatively, as an extrapolation on minimum values.

Proposal: Specify that the mean value be used. For clarity, add the trend line used for extrapolation in Figure 2.

Basis of proposal: n/a

Comment #13: Page 24, Section 12.2

Statement in DG: Figure 3, paragraph on page 24

Description of Concern: Figure 3 seems to be inconsistent with the accompanying text.

Basis for concern: The text provides a ductility limit of 3.1%, but Figure 3 shows a ductility limit of 2%.

Proposal: Delete the "ductility limit" line in Figure 3 or provide other clarification.

Basis of proposal: n/a

Comment #14: Page 7, Section 2

Statement in DG: "the beta layer will retain ductility as long as its oxygen content is low (e.g., <0.6 weight parts per million (wppm))"

Description of Concern: There is a typographical error in the units.

Basis for concern: "Weight parts per million (wppm)" appears to be a typographical error for "weight percent (wt%)". See page 37 of NUREG/CR-6967, which states "an average oxygen content of ≈0.6 wt.% is enough to embrittle the Zry-4 prior-beta layer following quench."

Proposal: Correct the text to read "the beta layer will retain ductility as long as its oxygen content is low (e.g., <0.6 wt %)"

Basis of proposal: n/a

Comment #15: Page 11, Section 5.1

Statement in DG: "The cooling rate from 1,200 °C to the quench temperature (i.e., the wetting temperature at which very rapid cooling occurs) may be important, but it is less critical than the heating rate. The cooling rate to the quench temperature should be >2 °C/s (e.g., <200 seconds from 1,200 °C to 800 °C). Use of slower cooling rates should be justified."

Description of Concern: The text prevents use of direct quench from the oxidation temperature.

Basis for concern: Direct quench is used in the industry for PQD testing and is an acceptable approach.

Proposal: Change text to read "Samples may be quenched from the oxidation temperature or partially cooled before quenching. The cooling rate from 1,200 °C to the quench temperature (i.e., the wetting temperature at which very rapid cooling occurs) may be important, but it is less critical than the heating rate. If samples are cooled before quenching, the cooling rate to the quench temperature should be >2 °C/s (e.g., <200 seconds from 1,200 °C to 800 °C). Use of slower cooling rates should be justified."

Basis of proposal: Investigators have reported that there is no effect of direct quenching on ductility for quench temperatures ≥ 800 °C as evidenced in the paper, J.C. Brachet *et al.* "Hydrogen Content, Pre Oxidation and Cooling Scenario Influences on Post-Quench Mechanical Properties of Zy-4 and M5® Alloys in LOCA Conditions - Relationship with the Post-Quench Microstructure" published in Zirconium in the Nuclear Industry, ASTM 15th International Symposium, Sun River, USA, 2008 compares the PQD behavior between several cooling scenarios. This paper shows no difference in ring compression test results (i.e., ductile vs. brittle) between direct quench from 1200°C and slow (<1°C/s) cooling down to 800°C on pre-hydrided Zy-4 at 600ppm, ≈6.2% measured ECR. They show the consistent results (ductile vs. brittle) with the ANL results for a ≈11°C/s cooling rate down to 800°C then quenched (see Table 54 of NUREG-6967).

Comment #16: Page 12, Section 6.1

Statement in DG: "Type S (Pt/10%Rh-Pt) TCs should be used to record temperature and control furnace power"

Description of Concern: The recommendations are overly restrictive.

Basis for concern: Other types of temperature measurements, such as Type R thermocouples and pyrometers, are adequate but are ignored. The current wording allows only one type of temperature measurement.

Proposal: "Type S (Pt/10%Rh-Pt) TCs are an example of an acceptable means to record temperature and control furnace power, but others can be demonstrated as adequate with the provisions of the thermal benchmarking section."

Basis of proposal: Experience in the EDGAR and CINOG tests has shown acceptable results with pyrometers for temperature control.

Comment #17: Page 14, Section 6.3

Statement in DG: "For Zr-lined Zry-2 and alloys of Zr-1 and niobium [emphasis added], the measured weight gain at 1,000 °C is considerably lower than the CP-predicted weight gain."

Description of Concern: There is a typographical error.

Basis for concern: n/a

Proposal: Change the quoted text to "For Zr-lined Zry-2 and alloys of zirconium with 1% niobium, the measured weight gain at 1,000 °C is considerably lower than the CP-predicted weight gain."

Basis of proposal: n/a

Comment #18: Page 17, Section 8.4

Statement in DG: "After the target test time has been reached, furnace power should be turned off or decreased in a controlled manner while steamflow is maintained. The rate of temperature decrease will depend on the heating method used and the method of removing the sample from the furnace. For in situ cooling, the steamflow should be maintained until the sample temperature reaches 800 °C."

Description of Concern: The text prevents use of direct quench from the oxidation temperature.

Basis for concern: Direct quench is used in the industry for PQD testing and is an acceptable approach.

Proposal: Change text to read "After the target test time has been reached, samples may be quenched immediately or furnace power may be turned off or decreased in a controlled manner while steamflow is maintained. The rate of temperature decrease will depend on the heating method used and the method of removing the sample from the furnace. If the sample is cooled before quenching, the steamflow should be maintained until the sample temperature reaches 800 °C."

Basis of proposal: Investigators have reported that there is no effect of direct quenching on ductility for quench temperatures ≥ 800 °C as evidenced in the paper, J.C. Brachet *et al.* "Hydrogen Content, Pre Oxidation and Cooling Scenario Influences on Post-Quench Mechanical Properties of Zy-4 and M5® Alloys in LOCA Conditions - Relationship with the Post-Quench Microstructure" published in Zirconium in the Nuclear Industry, ASTM 15th International Symposium, Sun River, USA, 2008 compares the PQD behavior between several cooling scenarios. This paper shows no difference in ring compression test results (i.e. ductile vs. brittle) between direct quench from 1200°C and slow (<1°C/s) cooling down to 800°C on pre-hydrided Zy-4 at 600ppm, ≈6.2% measured ECR. They show the consistent results (ductile vs. brittle) with the ANL results for a ≈11°C/s cooling rate down to 800°C then quenched (see Table 54 of NUREG-6967).

Comment #19: Page 19, Section 11.1

Statement in DG: "The TC or TCs used to control furnace or oven power corresponding to a ring test temperature of 135 °C should be calibrated to an NIST-traceable standard. The TC vendor provides this service for a fee and supplies a certificate of calibration along with the TC. The calibration should be performed at 135 °C. A variety of TCs could be used at this low temperature. Type K (chromel-alumel) TCs are recommended. The standard deviation between the TC reading and the NIST-traceable standard is quite low (e.g., ±0.3 °C for room temperature (RT) to 200 °C)."

Description of Concern: The recommendations are overly restrictive.

Basis for concern: Other types of temperature sensors (such as resistance thermometers) are appropriate, but are ignored in the DG.

Proposal: Change text to read "For tests at 135 °C, the devices used to control and measure temperature should be calibrated to recognized standards." In the first paragraph of Section 11.2, change all occurrences of "TC" to "temperature sensor".

Basis of proposal: The modification allows for other qualified temperature measurements to be utilized. Previously used methods should not be the only acceptable approach.

Comment #20: Page 20, Section 11.2

Statement in DG: "The crosshead displacement rate for ring-compression samples should be in the range of 0.083 [emphasis added] to 0.033 mm/s (0.5 to 2 mm/minute)."

Description of Concern: There is a typographical error in the converted value for the lower displacement rate.

Basis for concern: Converted values are not equivalent.

Proposal: Change the quoted text to "The crosshead displacement rate for ring-compression samples should be in the range of 0.0083 to 0.033 mm/s (0.5 to 2 mm/minute)."

Basis of proposal: n/a

Comment #21: Page 21, Section 11.4

Statement in DG: "Based on the experience reported in EP-Ref. 1, load drops in the range of 30–50% indicate a single through-wall crack, which may be very tight or loose because of recoil following test termination. For tight cracks, an accurate posttest diameter can be measured in the loading direction. For a single loose crack, the posttest diameter reading is not very accurate."

Description of Concern: It appears that a diameter measurement is suspect if it is for a sample with a loose crack, but that is not clearly stated. There is also no discussion on how to determine whether a crack is tight or loose.

Basis for concern: The guidance is not clear.

Proposal: Provide clarification on what constitutes a tight or loose crack and on the validity of data from samples containing them.

Basis of proposal: n/a

Comment #22: General Comment

Statement in DG: In several places throughout the guide, phrases such as "standards that are traceable to NIST" and "NIST-traceable standards" are used.

Description of Concern: Measuring and test equipment need not be calibrated to standards that are traceable to NIST to be acceptable.

Basis for concern: Metrological standards are not set exclusively by NIST. For example, laboratories outside the U.S. may rely on other measurement standards.

Proposal: Change the quoted text to "recognized standards".

Basis of proposal: 10 CFR 50, Appendix B, item XII does not require the use of a particular measurement standards laboratory.

Comment #23: General Comment

Statement in DG: The AREVA cladding M5® is referred to as simply M5 throughout the guide.

Description of Concern: M5 is a registered trademark of AREVA and should always be represented as M5®.

Basis for concern: n/a

Proposal: Modify DG-1262 to use M5® and include a footnote at the end of the main document as "M5® is a registered trademark of AREVA NP."

Basis of proposal: n/a

Enclosure 5

AREVA Comments on Draft Regulatory Guide 1263

Comment #1: On page 5 of DG-1263 and throughout the remainder of the document

Statement in DG: The AREVA cladding M5® is referred to as simply M5.

Description of Concern: M5 is a registered trademark of AREVA and should always be represented as M5®.

Basis for concern: n/a

Proposal: Modify DG-1263 to use M5® and include a footnote at the end of the main document as "M5® is a registered trademark of AREVA NP."

Basis of proposal: n/a

Comment #2: Page 5, Just above Figure 2

Statement in DG: DG-1263 states "... the applicability of the ECR limits given in Figure 2 of DG-1263 is restricted to the alloys tested in the Argonne program (Zr-2, Zr-4, ZIRLO, and M5®)."

Description of Concern: The testing at Argonne not only established the response of specific cladding alloys to potential embrittlement but also established the effect of selected alloying elements and concentrations to potential embrittlement conditions.

Basis for concern: For this family of zirconium alloys, embrittlement occurs due to oxygen increasing the oxygen stabilized alpha layer in the cladding. The concentration of hydrogen in the cladding controls the high temperature diffusivity and solubility of oxygen in the cladding, increasing both with increased hydrogen. This allows the oxygen content in the cladding to rise to levels that embrittle the cladding when cooldown occurs.

Proposal: This process is well understood and AREVA recommends that the applicability of the ECR limits presented in Figure 2 of DG-1263 be expanded to include those alloys within the same family of the alloys tested at Argonne. This can be accomplished by substituting "Zirconium-alloy cladding materials of the same family of alloys as those tested in NRC's LOCA research program" for "Zirconium-alloy cladding materials tested in NRC's LOCA research program" in the regulatory guide. The following paragraph discusses the family of alloys tested at ANL.

The definition of "family of alloys" proposed by AREVA comprises alloys created with the alloying elements included in the ANL test program with reasonable extensions of their concentrations. As such the family would consist of zirconium alloys made up of Nb<1.5%, Fe<0.3%, Sn<2%, Cr<0.2%, Ni<0.2%, O >900ppm. AREVA suggests that such a definition be added to DG-1263 at a convenient location within the discussion of Figure 2.

Basis of proposal: n/a

Comment #3: Just after Figure 2

Statement in DG: "For zirconium-alloy cladding materials not tested in the NRC's LOCA research program, a demonstration of comparable performance with the established database is necessary."

Description of Concern: What constitutes a new cladding alloy is unclear.

Basis for concern: Simply exceeding the bounds of an existing alloy specification does not signify that the alloy is a "New Alloy" for the purposes of LOCA induced embrittlement criteria.

Proposal: After the presentation of the alloy coverage of Figure 2, just prior to the discussion of required justifications, DG-1263 should provide a discussion of how the determination that an alloy of differing composition is actually a "New Alloy" and not just an extension of an existing family of alloys. "New Alloy" could include either new alloying elements or, limits beyond those defined in comment 2 for already known alloying elements (Sn, Nb, Fe, Cr, Ni, O).

A vendor wishing to qualify an extension to an alloy family could present material and rationale supporting the extension to the NRC. If the NRC agrees that the revised alloy makeup will not impact PQD criteria then the referenced alloy family would be expanded with its post quench ductility limit curve applicable to all members. AREVA proposes that this approach be added to DG-1263.

Basis of proposal: n/a

Comment #4: Pages 6 to 11 of DG-1263

Statement in DG: Starting on page 6 of DG-1263 and continuing on to page 11 guidance is provided on developing a suitable PQD ECR criteria curve for an alloy that differs from those for which Figure 2 has been deemed applicable or for a differing peak oxidation temperature. Three categories and guidance outlines are given:

1. Methodology for Demonstrating Consistency with the Existing Database for New Cladding Alloys,
2. Methodology for Establishing a Zirconium-Alloy-Specific Limit, and
3. Methodology for Establishing Analytical Limits at Peak Oxidation Temperatures Less than 1,204 °C (2200 °F).

The guidance provided under each is divided into three material categories:

1. As-received cladding material,
2. Prehydrided cladding material, and
3. Irradiated cladding material.

Description of Concern: The methodologies described are nearly identical between the three guidance outlines and the three material categories. AREVA believes that a more concise description would contribute to ease of understanding and facilitate both submittals for review and the review itself.

Basis for concern: n/a

Proposal: Modify DG-1263 as describe below:

1. As-received and prehydrided cladding could be combined under the heading "unirradiated cladding."
2. There is no need to specify three tests near each ECR level being tested. If a test is conducted at or above the desired ECR limit level and the sample is ductile by the criteria of DG-1262, there is no need for testing at lower ECRs at that hydrogen level. If the NRC believes that repeatability must be further demonstrated, it would be better to test at nearby hydrogen concentrations as opposed to differing ECR levels. Nearby hydrogen concentrations would verify repeatability and confirm the smooth curvature of the limit line.

   If the test result is not ductile, by the criteria of DG-1262, then a second sample should be tested at a lower ECR level. The target ECR could be selected as one that is expected to result in a ductile sample. If interpolation or averaging is to be part of the evaluation, it is important to ensure that each test included results in a measurable amount of plastic deformation. Results with no ductility and those with ductility cannot be meaningfully interpolated or averaged.
3. For irradiated cladding, AREVA considers the requirement to be within 50 ppm of the hydrogen target to be too stringent. Further, an examination of expected decrease in fuel rod power capabilities with burnup and the characteristic exponential decrease of the allowable ECR limit with burnup reveals that there exists a burnup at which the margin to embrittlement will be minimized. This point is less than the maximum operational burnup and at a hydrogen concentration below the maximum expected. AREVA estimates this to occur at approximately 75 to 80 percent of the maximum hydrogen concentration. AREVA, therefore, proposes that irradiated testing occur within 100ppm of two hydrogen content points:

1. The maximum expected hydrogen content during operation, and
2. At 75 percent of the maximum expected hydrogen content during operation.

Irradiated samples should be tested at two levels of hydrogen. For alloys with limited hydrogen pickup during operation those points typically less than 200 ppm at maximum operational burnup should be selected to provide substantial experimental support for the application of the desired limit curve.

The irradiated testing must confirm the desired ECR limit curve. If the curve is not confirmed, the testing should be expanded such that the burnup-embrittlement dependency of the alloy can be determined.

Basis of proposal: n/a

Comment #5: Integral Time at Temperature definition

Statement in DG: Throughout DG-1263

Description of Concern: "Integral Time a Temperature" is a key concept used throughout the guide and a definition would be appropriate.

Basis for concern: n/a

Proposal: The Glossary should define how "Integral Time at Temperature" is defined and used in the regulatory guide. This could be as follows:

> The process of embrittlement at high temperature is dependent on the diffusion of oxygen into the cladding and as such depends on the cladding temperature and the span of time for which the cladding is exposed to that temperature. A convenient way to establish this influence is through the application of a prediction of the oxide layer increase during the transient. ECR during the transient, as calculated with the Cathcart-Pawel correlation, is used to integrate time-at-temperature in this Regulatory Guide.

Basis of proposal: n/a

Comment #6: Page 12, Qualification of Hydrogen Pickup Models

Statement in DG: DG-1263 states in the first paragraph "The post-irradiation examination data supporting the hydrogen uptake model should include values for multiple burnup levels, encompass all applicable operating conditions and reactor coolant chemistry, and should quantify axial, radial, and circumferential variability."

Description of Concern: The requirements for measurement of hydrogen content should be no more than that which is to be used in the determination of the ECR limit, which, by DG-1263, does not include radial and circumferential variability.

Basis for concern: In "Accounting for Uncertainty and Variability in Hydrogen Content," DG-1263 states "the allowable CP-ECR should be based on predicted peak circumferential average hydrogen content ..." Therefore, only the highest circumferential average hydrogen value for a rod need be determined and the requirement for circumferential and radial measurements should be removed.

The suggestion to bound all operating conditions and coolant chemistries is potentially burdensome and perhaps detrimental to efforts to improve coolant chemistry (e.g., crud control).

Proposal: Radial and circumferential variability should be removed from this section of the DG. How the circumferential average is determined is up to the vendors and would need to be approved by NRC in the vendor methods report.

The requirement should be changed to state that the conditions over which the data is obtained should justify the applications of the hydrogen model to the operating conditions and coolant chemistry to which the model is applied. This would allow some provision for small alterations of conditions of application and for reasonable extrapolations.

Basis of proposal: n/a

Comment #7: Page 12, Qualification of Hydrogen Pickup Models

Statement in DG: This section of DG-1263 describes the requirements for data used to support the development of the required fuel rod hydrogen concentration models.

Description of Concern: Collecting data and developing models can take a substantial effort. Further, the required approval process can be extensive. In combination, these may impact the timely achievement of compliance, particularly for Category 1 plants.

Basis for concern: n/a

Proposal: The NRC could provide an additional figure of a bounding PQD limit curve, with CP-ECR versus burnup. Hydrogen is the dominant mechanism for the reduction in ECR and therefore burnup is not truly the independent variable. Therefore, this curve will likely be very conservative when compared to the results using the approved hydrogen model with Figure 2. This additional curve could be applied without knowledge of hydrogen content. It would have a very limited use and should only be an option. The demonstration of compliance would be conservative and would be replaced by a transition to Figure 2 using hydrogen content calculations upon need and the approval of a hydrogen model.

Basis of proposal: In order to apply Figure 2 (an acceptable analytical limit on peak cladding temperature and integral time at temperature), an approved hydrogen model is required. Considering data, model development, and NRC review, the effort for approval of these models will be substantial and they will be held proprietary by the fuel vendors. The development of an alternative ECR limit curve dependent on burnup would provide a conservative approach that would ease plant compliance to the rule and support the deployment of safer more embrittlement resistant claddings.

Comment #8: Page 15, Section C. Regulatory Position

Statement in DG: In footnote 3, the second sentence reads "For a zirconium alloy with an anticipated, end of life hydrogen content, the range of material conditions ..."

Description of Concern: n/a

Basis for concern: n/a

Proposal: AREVA believes this should read as "... end of life hydrogen content of 400 ppm, the range of material conditions ..."

Basis of proposal: n/a

Comment #9: Page 15, Section C. Regulatory Position 3

Statement in DG: DG-1263 Position (b) states "With the results of four oxidation levels, for each material condition called for in (a) above, determine the ECR range in which the transition from ductile-to-brittle behavior occurs and conduct three repeat oxidation and quench tests at each ECR level within this range using the guidance provided in DG-1262."

Description of Concern: The statement is not clear in that perhaps seven oxidation levels have been studied in (a) for pre-hydrided material not just four. The discussion in (b) appears to be about how the conduct of the irradiated testing is done. However, that testing is done in (a) and the expansion or continued development in (b) is not straight forward and confusing.

Basis for concern: n/a

Proposal: AREVA suggests that the wording be modified to more clearly replicate that of the "Methodology for Establishing a Zirconium-Alloy-Specific Limit" section (pages 7 through 9).

Basis of proposal: n/a

Comment #10: General Comment

Statement in DG: Throughout DG-1263

Description of Concern: DG-1263 discusses the concept of averaging the result of ring compression tests in order to establish an experimental result. The parameter to be averaged should be specifically identified.

Basis for concern: If, for example, the parameter is the characterization of the result as brittle or ductile, how will the averaging proceed? If the parameter is the permanent strain, then all tests to be averaged need to have resulted in some measurable amount of permanent strain.

Proposal: If the parameter is the permanent strain, then all tests to be averaged need to have resulted in some measurable amount of permanent strain. This needs to be made clear and then the examples in Appendix B need to be recast depending on the decision to allow interpolation of results as suggested in AREVA DG-1263, Comment #4.

Basis of proposal: n/a

Comment #11: Page 6, An Acceptable Analytical Limit on Peak Cladding Temperature and Integral Time at Temperature

Statement in DG: At the top of the page DG-1263 states, "The database established in the NRC's LOCA research program and the resulting analytical limit described in this regulatory guide are intended to provide a best-estimate limit [emphasis added] for the ductile-to-brittle transition for zirconium alloys."

Description of Concern: The term "best-estimate" is not clearly defined

Basis for concern: n/a

Proposal: AREVA requests that the meaning of best estimate as applied in this regulatory guide be clarified either at this point or in the glossary. From the remainder of the discussions, it is clear that part of the meaning is that there is no retained margin in the curve. A possible presentation of this would be:

> The curve is a best estimate in that the NRC has confidence that the transition from ductile to brittle lies near but not below the line.

Basis of proposal: n/a

Comment #12: The Second Page 3, "Existing Embrittlement Database"

Statement in DG: Near the bottom of page 3 DG-1263 states, "... verify the following ductility criteria: average permanent strain ≥1.0% or, if permanent strain cannot be measured, the average ring compression test (RCT) offset strain ≥ 1.41% + 0.1082 Cathcart-Pawel equivalent cladding reacted (CP-ECR) (Ref. 10). Rounded to the nearest tenth of a percent, ..."

Description of Concern: It is not readily apparent that the RCT equation is the correlation developed in Appendix A and the units for Cathcart-Pawel are not specified.

Basis for concern: n/a

Proposal: Clarify the wording of the RCT equation as follows:

... verify the following ductility criteria:

- Average permanent strain ≥1.0% or,
- if permanent strain cannot be measured, use the Equation A.3 for the average ring compression test (RCT) offset strain as a function of Cathcart-Pawel equivalent cladding reacted (CP-ECR) (Ref. 10):

  Average RCT offset strain ≥ 1.41 + (0.1082*CP-ECR)

  where the offset strain and CP-ECR are in units of percent.

  Rounded to the nearest tenth of a percent, ...

Basis of proposal: n/a

Comment #13: Page 7, "Methodology for Establishing a Zirconium-Alloy-Specific Limit"

Statement in DG: Within the first paragraph of "Methodology for Establishing a Zirconium-Alloy-Specific Limit" DG-1263 states "In some instances, a zirconium-alloy cladding material may experience the transition from ductile to brittle behavior at a higher level [emphasis added] of oxidation than the established database."

Description of Concern: This statement is not complete.

Basis for concern: n/a

Proposal: AREVA believes that this underlined phrase should be "higher or lower level."

Basis of proposal: n/a

Comment #14: Page 13-14, Double-Sided Oxidation

Statement in DG: DG-1262 contains a section titled "Accounting for Double-Sided Oxidation Due to Fuel Cladding Bond Layer." The subsequent text in this section states "To account for the observation that oxygen can diffuse into the cladding metal during a LOCA from the ID, one acceptable approach would be to calculate two-sided local oxidation for fuel rods with a local (nodal) exposure beyond 30 GWd/MTU."

Description of Concern: The title and text in the section could lead to a misinterpretation between the phenomena (oxygen ingress vs. interior oxidation) and the acceptable approaches for the phenomena.

Basis for concern: There is no inside oxidation during the transient except at a cladding rupture location.

Proposal: The title of this section should be changed to "Accounting for Oxygen Ingress from the Inside of the Cladding."

Within the second paragraph "one acceptable approach would be to calculate two-sided oxidation for fuel rods with..." should be changed to "one acceptable approach would be to use twice the oxidation on the exterior of the cladding for un-ruptured locations on fuel rods with ..."

Basis of proposal: n/a

Comment #15: General Comment for Consistency

Statement in DG: Page 14 through 17 Regulatory Position

Description of Concern: n/a

Basis for concern: If AREVA DG-1263, Comment #4 is adopted, then the regulatory position would not be compatible.

Proposal: If AREVA DG-1263, Comment #4 is adopted, then the regulatory position should be modified to be compatible. If AREVA DG-1263, Comment #4 is not adopted, then prehydrided should be included in the list in the first sentence of 2.e.

Basis of proposal: n/a

Comment #16: Appendix B

Statement in DG: Entire Appendix B

Description of Concern: If AREVA DG-1263, Comment #4 is adopted, then the Appendix B will not correspond.

Basis for concern: n/a

Proposal: If AREVA DG-1263, Comment #4 is adopted, then the Appendix B should be reviewed and modified to be compatible.

Basis of proposal: n/a