Westinghouse

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Westinghouse Electric Company
Nuclear Fuel
P.O. Box 355
Pittsburgh, Pennsylvania 15230-0355
USA

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Secretary
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

Direct tel: (412) 374-4643
Direct fax: (412) 374-3846
e-mail: greshaja@westinghouse.com
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October 27, 2009

ATTN: Rulemaking and Adjudications Staff

Subject: RIN 3150-AH42, Westinghouse Comments on the Advance Notice of Proposed Rulemaking on 10 CFR 50.46 Performance-Based Emergency Core Cooling System Acceptance Criteria (Non-proprietary)

On August 13, 2009, the Federal Register (FR) published an advance notice of proposed rulemaking (ANPR) and invited comment on a conceptual approach under consideration by NRC to revise the acceptance criteria for emergency core cooling systems (ECCS) for light-water nuclear power reactors.(**74** FR 40765).

This letter provides Westinghouse's general comments on the ANPR. Attachment 1 provides comments on the four NRC objectives of the proposed rulemaking; Attachment 2 provides comments on specific issues for consideration cited by NRC; Attachment 3 provides additional comments on the Approaches for Determining the Acceptability of Zirconium-Based Cladding Analytical Limits discussed in Appendices A and B (**74** FR 40774); Attachment 4 provides detailed comments on the NRC's draft cladding oxidation and PQD testing methodology provided in Accession number: ML090900841; and Attachment 5 provides detailed comments on the NRC's draft breakaway oxidation testing methodology provided in Accession number: ML090840258.

Westinghouse supports the NRC's objective to "Expand the applicability of §50.46 to include any light-water reactor fuel cladding material", and further supports the NRC's proposed approach of specifying that all fuel cladding material used in LWRs, without regard to its composition, must satisfy the three general conditions which currently exist as the criteria, specified in § 50.46(b)(3) Maximum hydrogen generation, § 50.46(b)(4) Coolable geometry, and § 50.46(b)(5) Long-term cooling.

On-going and future testing and fuel examinations will continue to provide additional insight into fuel performance. To avoid the need for future exemption requests and / or rulemaking, specific numerical acceptance criteria and implementation details should not be included in the new rule, but rather should be provided in Regulatory Guides. This would allow flexibility to revise the details as new data are obtained and new cladding materials are licensed.

The ANPR indicates that two approaches to establish analytical limits are under consideration. In one approach (Approach A), the NRC would establish the limits based upon the existing data. In the other approach (Approach B), the applicant would propose analytical limits for NRC approval. To maintain flexibility, both approaches should be allowed by the new rule. This

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would provide a generic set of NRC-established limits, but would allow applicants to establish new limits as additional data are obtained and /or new cladding materials are developed.

The existing ECCS regulations include significant conservatism, including assumptions in the LOCA methodology, as well as requiring that the clad remain ductile to demonstrate that coolable geometry is maintained. Care should be taken in the rulemaking and associated regulatory guidance to avoid adding excessive conservatism (e.g. by requiring bounding treatments of uncertainties associated with the new limits).

The NRC's third objective of the proposed rulemaking is to revise the LOCA reporting requirements. The existing reporting requirement on peak clad temperature (PCT) has been adequate. The benefits of the proposed change are not clear from the ANPR, except for increasing the PCT reporting threshold for analyses with PCT < 2090 °F. In the absence of clear benefits, the reporting requirements should not be changed, except to extend the requirement to include clad oxidation.

Existing regulations are adequate to address breakaway oxidation and crud.

Finally, in the ANPR and the work leading up to it, NRC has identified no substantial safety issue affecting the continued safe operation of nuclear power plants. Given the significant effort to demonstrate compliance with the proposed new rule and the lack of safety significance, the rule should allow a period of time suggested to be on the order of five years from NRC approval of updated vendor evaluation models (EMs) for licensees to demonstrate compliance.

Westinghouse appreciates the opportunity for stakeholder involvement provided by the ANPR process. The existing ECCS regulations have been adequate to assure public health and safety since their inception. Care should be taken in revising these regulations to assure that the new rule is flexible and implements needed changes without unduly increasing the regulatory burden on licensees. We look forward to working with NRC and other stakeholders through the remainder of the ANPR process and the subsequent rulemaking process

Correspondence regarding this letter and the attachments should reference LTR-NRC-09-51 Rev. 1 and should be addressed to J. A. Gresham, Manager, Regulatory Compliance and Plant Licensing, Westinghouse Electric Company LLC, P.O. Box 355, Pittsburgh, Pennsylvania, 15230-0355.

Very truly yours,

J. A. Gresham, Manager
Regulatory Compliance and Plant Licensing

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Attachment 1
Westinghouse Comments on Rulemaking Objectives
(Non-Proprietary)

Westinghouse Electric Company
P.O. Box 355
Pittsburgh, Pennsylvania 15230-0355

Objective 1

Expand the applicability of § 50.46 to include any light-water reactor fuel cladding material.

Westinghouse Comment

Westinghouse supports this objective and agrees that this objective is best achieved by specifying key performance requirements in the rule with details on how to demonstrate compliance with the rule provided in Regulatory Guidance documents.

Westinghouse supports the proposed approach of specifying that all fuel cladding material used in LWRs, without regard to its composition, must satisfy the three general conditions which currently exist as the criteria specified in § 50.46(b)(3) Maximum hydrogen generation, § 50.46(b)(4) Coolable geometry, and § 50.46(b)(5) Long-term cooling. It is understood that the § 50.46(b)(3) criterion would be modified to limit generation of any combustible gas, rather than just hydrogen.

Westinghouse also supports the proposed NRC approach of developing criteria for zirconium-based alloys based on the results of the NRC's LOCA research program to assure that coolable geometry is maintained by maintaining clad ductility. This approach will provide clearly conservative limits that can be applied by all current licensees in evaluating their ECCS performance.

However, this approach retains significant conservatisms, including the use of clad ductility to assure coolable geometry, a limited database and bounding test conditions. For this reason, it is important that flexibility be maintained in the rule to accommodate the results of additional testing and research at more representative conditions. This flexibility is best maintained by limiting the rule to the three general conditions cited above that are called out in the current rule, and providing the detailed criteria for meeting these conditions in a Regulatory Guide. The Regulatory Guide could be updated with significantly less effort than would be required to change the rule.

The Regulatory Guide should specify the detailed criteria that are to be met to demonstrate compliance with the general conditions cited in the rule. The Regulatory Guide should also allow the option of using generic limits based on the NRC's LOCA research program or alternate limits developed by the applicant based on additional testing and research for specific cladding materials at representative conditions.

Objective 2

Establish performance-based requirements and acceptance criteria specific to zirconium-based cladding materials that reflect recent research findings.

Westinghouse Comment

Westinghouse supports the modification of the rule to establish performance-based requirements. The rule should not be limited to zirconium-based alloys, but should apply to all cladding materials. In order to maintain flexibility and avoid the need for new rulemaking as additional testing and research are done and new cladding materials are introduced, acceptance criteria that can be used to demonstrate compliance with the rule should be provided in Regulatory Guides or other appropriate NRC documents. Developing acceptance criteria to maintain clad ductility is a conservative approach to assuring that the fuel is maintained in a coolable geometry. While this conservative approach simplifies the development of the acceptance criteria, regulatory guidance should allow the use of alternate criteria for demonstrating that the coolable geometry requirement is met.

Tests simulating LOCA conditions show that the ballooned region of the cladding is embrittled and this region of the cladding is assumed to be failed in a LOCA analysis. Therefore, the requirement to maintain ductility should not apply to the ballooned region and clad adjacent to the ballooned region.

The ANPR indicates that "The NRC intends to issue a regulatory guide detailing an acceptable experimental test methodology for defining analytical limits…". Care should be taken in developing such a guide, to avoid overly prescriptive experimental procedures and / or specifications. Such a guide should focus on requirements that are to be met by the testing and provide a sample procedure that is an acceptable way of meeting those requirements. This approach would allow alternate procedures to satisfy the same requirements. Development of an ASTM or other broadly accepted industry test standard should be encouraged, to draw on the expertise of the broad community of technical experts in developing the test procedures. This comment also applies to proposed Regulatory Guides detailing other test methodologies (e.g. to determine the time to breakaway oxidation).

Two approaches are outlined in the ANPR for developing analytical limits:

Approach A - Analytical limits defined within regulatory guidance

Approach B - Cladding specific analytical limits defined by an applicant.

Both approaches should be allowed by the Regulatory Guide. Approach A would provide generic, conservative limits that would apply to any zirconium-based alloy provided consistency with the limits is demonstrated for new alloys. However, it is recognized that excess conservatism in these limits can be reduced by performing additional testing (e.g. by testing at temperatures more representative of those that can be attained by higher burnup fuel in a hypothetical LOCA). Approach B would allow applicants to obtain this additional data and develop more appropriate limits. Approach

B could also be needed for new cladding materials that have not yet been approved by NRC. It is recognized that the burden of proof for alternate limits would be on the applicant in Approach B.

The ANPR also discusses the phenomenon of breakaway oxidation for zirconium-based alloys and proposes prescriptive approaches to demonstrate that the consequences of a LOCA will not be adversely impacted by breakaway oxidation. Westinghouse recognizes the importance of addressing the potential impact of breakaway oxidation in the licensing of a cladding alloy. Given the conservatism of the current Appendix K small break Evaluation Models, information available in existing UFSARs should be adequate to establish an acceptable time to breakaway oxidation.

Objective 3

Revise the LOCA reporting requirements. Redefining a Significant Change or Error.

Westinghouse Comment

The existing reportability requirement in 10 CFR 50.46(a)(3)(i) currently "defines a significant change or error as one that results in a calculated peak cladding temperature (PCT) different by more than 50 °F (28 °C) from the temperature calculated for the limiting transient using the last acceptable model, or is a cumulation of changes and errors such that the sum of the absolute magnitudes of the respective temperature changes is greater than 50 °F (28 °C)." This requirement has been adequate in the past, and no compelling need to reduce the reporting threshold has been identified. Therefore additional regulatory burden is not warranted. Increasing the PCT reporting threshold to 100 °F for analyses with PCT < 2090 °F would reduce regulatory burned with no impact on public health and safety; this change should be implemented.

The ANPR indicates that consideration is being given to expanding the reporting requirement to clad oxidation (CP-ECR) and breakaway oxidation. Since the CP-ECR limit is not a single number, but will vary dependent on the condition of the cladding, it would be appropriate to define what constitutes a significant change or error in terms of margin to the acceptance criteria. It would be best to apply a simple definition, perhaps requiring reporting when the licensee is within 5% of the CP-ECR limit. (For example, if the limit were 10% CP-ECR, reporting would be required for changes that cause the calculated CP-ECR to be $\geq$ 9.5%).

While it is important to consider breakaway oxidation in evaluating the consequences of a LOCA, there is no need for a new reportability requirement on the time to breakaway oxidation. 10 CFR 50 Appendix B requires that a supplier establish a program to assure the quality of its products. These programs are approved by NRC and suppliers are routinely audited by their customers for compliance with these programs. Given that the need to account for the time to breakaway oxidation when licensing new cladding materials or qualifying significant manufacturing process changes has been identified, suppliers must include provisions to assure that the manufacturing processes yield cladding with acceptable time to breakaway oxidation. These provisions are subject to audit by customers and by NRC. Furthermore, if cladding were produced that did not exhibit acceptable time to breakaway oxidation, the requirements of 10 CFR 21 would pertain, and the occurrence would be reported to NRC if "the defect could create a substantial safety hazard."

Thus, the existing provisions of 10 CFR 50 Appendix B and 10 CFR 21 are adequate and no additional specific reportability requirement is needed on the time to breakaway oxidation.

Objective 4

Address the issues raised in PRM-50-84, which relate to crud deposits and hydrogen content in fuel cladding.

Westinghouse Comment

The ANPR cites three requests for rulemaking that are to be addressed under this objective.

(1) Establish regulations to limit the thickness of crud and oxide layers on zirconium clad fuel,
(2) Amend the rule to require that the steady state temperature distribution and stored energy in the reactor fuel at the onset of a postulated LOCA be calculated by factoring in the role that the thermal resistance of crud deposits and / or oxide layers play in increasing the stored energy of the fuel,
(3) Amend the rule to specify a maximum allowable percentage of hydrogen content in the cladding.

These requests were made in Petition for Rulemaking PRM-50-84. The ANPR then goes on to say that the third request is addressed by Objective 2 of the ANPR and does not discuss it further under Objective 4. Therefore, this comment focuses on the ANPR discussion related to requests (1) and (2) above.

The nuclear industry provided a response to requests for comments on this petition in a letter from NEI. The ANPR discusses the information provided in this letter and concludes that there is ambiguity in the current requirements in 10 CFR 50.46 and in the Standard Review Plan (NUREG -0800). The ANPR observes that:

"Recently, power reactor licensees have been submitting an increased number of license amendment applications requesting significant increases in licensed power levels. In some cases, these increases have reduced the margin between calculated ECCS performance and current ECCS acceptance criteria."

The ANPR then concludes that:

"This trend further supports the need to ensure that the effects of both crud and oxidation are properly accounted for in ECCS analysis."

The need to "ensure that the effects of both crud and oxidation are properly accounted for in ECCS analysis" does not equate with a need to revise the rule.

When license amendment applications are made to NRC they are scrupulously reviewed by the NRC for compliance with the requirements in 10 CFR 50.46 and the Standard Review Plan. In many cases, the applications and the NRC's conclusions are reviewed by ACRS. This provides ample opportunity to confirm that the effects of oxidation and crud are properly accounted for in ECCS analysis. Any ambiguity in the requirements can be addressed in the specific review of an individual license amendment application, in light of the actual margin to ECCS acceptance criteria that is demonstrated in that application. There is no need for additional regulations to address this issue.

The ANPR proposes that the regulations be amended to explicitly identify crud as one of the parameters that must be addressed in ECCS analysis models. In conjunction with this, the ANPR indicates that §50.46(a)(3)(i) reporting requirements would be expanded to include increases of crud layers beyond those accounted for in the ECCS analysis. The ANPR also proposes to require the inspection of one or more fuel assemblies every cycle to determine the actual thickness of crud on the fuel.

The existing review process is adequate to establish whether the effects of crud are properly accounted for in license amendment applications. As explained in the NEI letter provided previously on this issue, industry takes measures to control reactor coolant chemistry to avoid operation with significant crud on the fuel. Given that the existing review process is adequate and that the occurrence of significant crud buildup is an atypical event, there is no need for additional requirements to explicitly account for the effect of crud, or for the associated expansion of reportability and inspection requirements.

Attachment 2
Westinghouse Comments on Issues for Consideration
(Non-Proprietary)

Westinghouse Electric Company
P.O. Box 355
Pittsburgh, Pennsylvania 15230-0355

NRC Request for Comment 1

Objective 1 describes a conceptual approach to expanding the applicability of § 50.46 to all fuel cladding materials. Should the rule be expanded to include any cladding material, or only be expanded to include all zirconium-based cladding alloys? The NRC also requests comment on the potential advantages and disadvantages of the specific approach described that would expand the applicability beyond zirconium-based alloys. Is there a better approach that could achieve the same objective?

Westinghouse Comment 1

Westinghouse supports rulemaking Objective 1 of this ANPR, "Expand the applicability of § 50.46 to include any light water reactor fuel cladding material." This objective is best served by specifying that all fuel cladding materials used in LWRs, without regard to composition, must satisfy the three general conditions which currently exist as the criteria specified in § 50.46 (b)(3) Maximum hydrogen generation, § 50.46 (b)(4) Coolable geometry, and § 50.46 (b)(5) Long term cooling, with the understanding that the criteria would be modified as needed (for example: § 50.46 (b)(3) criterion would be modified to limit generation of any combustible gas rather than just hydrogen).

This approach to the rule change would address current and planned cladding materials and also allow innovative new materials which have the potential to increase safety margins and reduce operating costs.

NRC Request for Comment 2

The rulemaking objectives do not include expanding the applicability of § 50.46 to include fuel other than uranium oxide fuel (UO_2). Is there any need for, or available information to justify, expanding the applicability of this rule to mixed oxide fuel rods?

Westinghouse Comment 2

This rule should not limit fuel types to UO_2, or mixed oxide fuels. The use of performance based criteria eliminates the need to specify the fuel type or clad composition. The approach proposed by NRC to address Objective 1 and outlined in response to Request for Comment 1 assures that fundamental requirements are met. It is understood that the burden of proof in demonstrating that these criteria are met will be on the applicant, and that this burden may be greater for advanced fuel types and / or cladding compositions.

NRC Request for Comment 3

The NRC requests information related to the maximum time span with cladding surface temperature above 1200°F (649°C) for the full range of piping sizes and NSSS/ECCS design combinations. This information may be used to set a specified minimum time to breakaway in the proposed rule's applicability statement.

Westinghouse Comment 3

Many evaluation models are only applied to break sizes that have historically been limiting for that NSSS/ECCS design combination. Significant analysis work would be required to answer the specific question, however the small break LOCA temperature profiles previously provided in Figure II-2 of LTR-NRC-08-42 are believed to be at or near upper bound with respect to time above 1200°F for Westinghouse and CE designed plants. Most would be significantly shorter. It should be noted that existing NRC-approved evaluation models would not give realistic results, but rather, excessively conservative results for the following reasons:

- Westinghouse licensing basis SBLOCA analysis are performed with evaluation models per 10 CFR Appendix K requirements. These models have many conservative aspects including a 20% decay heat multiplier which in itself has been demonstrated to be very conservative.
- There are several operator actions that are not modeled in Westinghouse SBLOCA licensing basis analyses which, if considered, would prevent clad temperature excursions from exceeding 1,200°F for any length of time, even under Appendix K assumptions. There are two actions in particular which mitigate the SBLOCA transient. The first is a controlled reactor coolant system (RCS) cooldown which is performed when it is apparent that the RCS is not depressurizing in a timely manner. This is done by dumping steam from all intact steam generators in a prescribed manner. This action reduces break flow, increases ECCS flow and allows the accumulators to inject at an earlier point in the transient, all of which are beneficial to the SBLOCA transient. The second action not normally considered in standard safety analysis is also a cooldown, but in this case, it is an unrestricted one. After reactor trip, several key plant parameters are continually monitored as critical safety functions. This includes adequate core cooling which is indicated through core exit temperature measurements. If at any time in the transient core exit temperatures exceed 1,200°F outright, or exceed 700°F with a reactor vessel water level indication of core uncovery, the intact steam generators are depressurized at maximum rate. This has the same benefits as identified above, but the benefits occur much more rapidly.

Given the Appendix K conservatisms in the small break LOCA evaluation models used for Westinghouse and CE designed plants, and the lack of considerations of operator actions, information available in existing UFSARs should be adequate to establish an acceptable time to breakaway oxidation.

NRC Request for Comment 4

The NRC requests comment on the two approaches to establishing analytical limits for cladding alloys, as described in Section III.2 of this document and expanded upon in the Appendices, where limits on peak cladding temperature and local oxidation would be replaced with specific cladding performance requirements that define an adequate level of ductility which must be maintained throughout a postulated LOCA. In addition to general comments on these approaches, the NRC also seeks specific comment on the following related items.

Westinghouse Comment 4

The ANPR specifies two approaches to determining analytical limits, approaches A and B. In approach A the analytical limits would be defined by regulatory guidance. In approach B the analytical limits would be defined for a specific cladding material by the applicant.

The revised rule should allow either method to be used. The nominal limits proposed in approach A are based on assumptions and test conditions which are very conservative with respect to the expected behavior under a hypothetical LOCA event. One of the elements of this conservatism is the testing technique used to obtain the data. The high temperature oxidation is performed as close to 1204 °C as possible. This results in higher oxygen diffusion rates which in turn result in greater alpha layer growth and consequent embrittlement than would occur for the same ECR at lower temperatures

For LOCA analyses with relatively low transient oxidation, approach A would be a straightforward method for demonstrating compliance. For analyses with more oxidation, it may be appropriate to reduce the excess conservatism in the limit by basing the limits on more realistic test data. Possible methods of developing limits for approach B would include:

1. Determine empirical limits by performing post quench ductility (PQD) testing on samples oxidized over a lower temperature range. That data would be used to develop PCT-dependent limit lines of allowable ECR vs. hydrogen.
2. Develop models of oxygen diffusion and alpha layer growth such that the effect of the time-temperature history on PQD could be determined and the ECR margin could be determined.
3. Develop alternatives to ring-compression testing (RCT) to determine post quench ductility. LOCA basis testing is ongoing and new methods, including post quench testing methods, are being refined. See also Comment 6d.

NRC Request for Comment 4a

The NRC requests any further PQD ring-compression test data that may be available to expand the empirical database as shown in Appendix A of this document.

Westinghouse Comment 4a

Westinghouse currently does not have any additional PQD ring-compression test data.

NRC Request for Comment 4b

Because no cladding segments tested in the NRC's LOCA research program exhibited an acceptable level of ductility beyond a hydrogen concentration of 550 wppm (metal), analytical limits may be restricted to terminate at this point. Are any further PQD ring-compression test data available at hydrogen concentrations beyond 550 wppm which exhibited an acceptable level of ductility?

Westinghouse Comment 4b

Westinghouse is not aware of additional hydrogen charged ring test data other that data which has already been presented. However, restrained quench testing of irradiated cladding by JAEA in Reference 4-1 tested samples with up to 720 ppm hydrogen and showed no significant drop off in survivability, indicating that the survivability threshold is high than 720 ppm.

It is expected that the range in transition from ductile to brittle can be established in PQD testing for varying ECR and levels of hydrogen. Testing of unirradiated cladding with hydrogen pre-loaded to levels up to 1000 ppm (or higher if warranted) could provide the basis for limits. This is the objective of an ongoing Westinghouse test program that is co-funded by EPRI.

Reference 4-1: Fumihisa NAGASE, Toshinori CHUTO, Toyoshi FUKETA "Cladding Embrittlement under LOCA Conditions, Examined by Two Test Methodologies," pp 527-534, Proceedings of Top Fuel 2009, Paris, France, September 6-10, 2009.

NRC Request for Comment 4c

Ring-compression tests conducted on cladding segments with identical hydrogen concentrations oxidized to the same CP–ECR often exhibited a range of measured offset displacement. The variability, repeatability, and statistical treatment of these test results must be evaluated for defining generic PQD analytical limits. The NRC requests comments on the variability, repeatability, and statistical treatment of ductility measurements from samples exposed to high-temperature steam oxidation.

Westinghouse Comment 4c

The existing LOCA methods and the requirement of maintaining clad ductility as a means of assuring coolable geometry contain significant conservatisms. Other conservatisms are discussed in the response to Request for Comment 5b. The NRC evaluation of "The variability, repeatability, and statistical treatment of" test results should take these significant conservatisms into account. Significant effort to address these considerations is likely not warranted in light of the considerable inherent conservatisms in the LOCA methods. Care should be taken to avoid adding excess conservatism by applying bounding approaches in establishing CP-ECR limits.

NRC Request for Comment 5

Implementation of a hydrogen dependent PQD criterion requires an NRC-approved hydrogen uptake model. The sensitivity of hydrogen pickup fraction to external factors (e.g., manufacturing process, proximity to dissimilar metals, plant coolant chemistry, oxide thickness, crud, burnup, etc.) must be properly calibrated in the development and validation of this model.

NRC Request for Comment 5a

The NRC requests information on the size and depth of the current hotcell hydrogen database(s) and the industry's ability to segregate the sensitivity of each cladding alloy to each external factor and to quantify the level of uncertainty.

Westinghouse Comment 5a

The hydrogen data representative of the current database were presented at the 2009 Top Fuel Conference in the papers in References 5-1 and 5-2.

Reference 5-1: "Hydrogen Pick-Up Fraction for ZIRLO™ Cladding Corrosion and Resulting Impact on the Cladding Integrity," Garde et al, Proceedings of Top Fuel 2009 Paris, France, September 6-10, 2009, Paper 2136.

Reference 5-2: "Corrosion and Hydrogen Uptake Behavior and Modeling for Modern BWR Cladding Materials at High Burnup," Zhou et al, Proceedings of Top Fuel 2009 Paris, France, September 6-10, 2009, Paper 2020).

NRC Request for Comment 5b

Pre-test characterization of some irradiated cladding segments revealed significant variability in axial, radial, and circumferential hydrogen concentrations.

i. What information exists that could quantify this asymmetric distribution in the development of a hydrogen uptake model?

ii. What information exists that could inform the treatment of this asymmetric hydrogen distribution as a function of fuel rod burnup?

iii. This asymmetric hydrogen distribution could be addressed in future PQD ring compression tests on irradiated material by such requirements as orienting ring samples such that the maximum asymmetric hydrogen concentration is aligned with the maximum stress point or in prehydrided material by introducing asymmetric distribution during hydriding. The NRC requests comment on these or other methods to treat asymmetric hydrogen distribution.

Westinghouse Comment 5b

An example of hydrogen content variation can be found in Reference 5-3 where backscatter SEM was used to determine the hydrogen distribution in two cladding axial sections 180 degrees apart.

As explained in the Comment on item 4(c), the existing LOCA methods and the use of clad ductility as criterion to assure coolable geometry contain significant conservatisms. The evaluation of the variability in local hydrogen concentration in the cladding and its effects should take these significant conservatisms into account. Significant effort to address these considerations is likely not warranted in light of the considerable inherent conservatisms in the LOCA methods. The ANPR proposed criteria are based on assumptions and test conditions which are very conservative with respect to the expected behavior under a hypothetical LOCA event and thus increase the conservatism.

Reference 5-3: N(H)-02-027, PIE OF CIP0-1 FATHER ROD: Cladding oxide and hydride measurement in SEM, Wubeshet Sahle, 02/20/2001.

NRC Request for Comment 6

A draft proposed cladding oxidation and PQD testing methodology is provided at ADAMS Accession number ML090900841.

NRC Request for Comment 6a

The NRC requests comment on the details of the draft experimental methodology, including sample preparation and characterization, experimental protocols, laboratory techniques, sample size, statistical treatment, and data reporting.

Westinghouse Comment 6a

Westinghouse recommends that alloy-specific references be removed from the procedure. In particular, Westinghouse recommends that weight gains for all alloys be compared to Cathcart-Pawel or vendor-supplied databases.

Additional detailed comments on the draft experimental methodology are provided in Attachment 4.

NRC Request for Comment 6b

The NRC requests information on any ongoing or planned testing programs that could exercise the draft experimental methodology to independently confirm its adequacy.

Westinghouse Comment 6b

EPRI is sponsoring a program conducted by Westinghouse to evaluate the ductility of Zircaloy-4 cladding specimens. The testing will include oxidation temperatures ranging from 800°C to 1200°C with hydrogen levels up to 1000 ppm. Ductility will be assessed by ring-compression tests at 135 °C following the guidance in the proposed test procedure. The goal of the testing is to establish ductility limits as a function of ECR, peak cladding temperature, and hydrogen content.

NRC Request for Comment 6c

Unirradiated cladding specimens pre-charged with hydrogen appear to be viable surrogates for testing on irradiated cladding segments. However, the NRC's position remains that future testing to support cladding approval reviews include irradiated material without further confirmatory work to directly compare the embrittlement behavior of irradiated material to hydrogen pre-charged material at the same hydrogen level. The NRC's LOCA research program reports PQD test results on twenty irradiated fuel cladding segments of varying zirconium alloys and hydrogen concentrations that underwent quench cooling. The NRC requests information on any ongoing or planned *testing aimed at replicating these twenty PQD tests for the purpose of validating a pre-hydrided surrogate.*

Westinghouse Comment 6c

Westinghouse has no current plans to perform additional testing to replicate the NRC LOCA PQD tests that were performed to correlate pre-hydrided samples and irradiated samples.

NRC Request for Comment 6d

The NRC is considering defining an acceptable measure of cladding ductility as the accumulation of ≥1.00 percent permanent strain prior to failure during ring-compression loading at a temperature of 135 °C and a displacement rate of 0.033 mm/sec. Recognizing the difficulty of measuring permanent strain, the NRC requests comment on alternative regulatory criteria defining an acceptable measure of cladding ductility.

Westinghouse Comment 6d

The difficulty in measuring permanent strain following a ring-compression test compromises the utility of that metric for assessing brittle behavior. Westinghouse recommends that alternate definitions of cladding ductility be permitted with the intent of identifying techniques (e.g., 3-point bend test) that reduce scatter, are representative of the actual post-LOCA loading conditions and may provide consistent results between test laboratories. Future industry programs to develop standardized testing procedures should not be precluded from establishing alternate acceptable measures of cladding ductility.

NRC Request for Comment 7

The proposed revisions to § 50.46 include a new testing requirement related to breakaway oxidation. Due to the observed effects of manufacturing controlled parameters (e.g., surface roughness, minor alloying, etc.) on the breakaway phenomena, the proposed approach would include periodic testing requirements to ensure that both planned and unplanned changes in manufacturing processes do not adversely affect the performance of the cladding under LOCA conditions.

Westinghouse Comment 7

Breakaway oxidation is a phenomenon that has been associated with clad ductility and therefore, it should be evaluated in assessing the performance of the fuel during a LOCA. To assure this, it is suggested that the regulatory guidance provided by the NRC for implementation of the new rule indicate that breakaway oxidation of the cladding should not occur based on the existing ECCS analysis spectra Vendors would then be responsible for establishing the time to breakaway oxidation for their cladding materials and licensees would be responsible for confirming that this time is not exceeded based on their existing ECCS analysis.

Data presented in RIL 0801 show that alloy composition and manufacturing processes can impact the time it takes a particular cladding sample to achieve breakaway oxidation. However, the data do not show that the variations in alloy composition and manufacturing process parameters that are allowed during cladding fabrication have significant impact on the time to breakaway oxidation.

Fuel cladding vendors establish the performance characteristics of new alloys and report those characteristics to NRC to obtain approval for a new cladding material. Furthermore, vendors perform qualification testing when new cladding material is introduced to establish that the product meets performance requirements. These qualification tests are performed in accordance with the vendors' Quality Assurance (QA) programs, and those QA programs assure that material is produced in accordance with the alloy specification and qualified manufacturing process. Each vendor's Quality Assurance program has been developed to meet the requirements of 10 CFR 50 Appendix B and has been approved by NRC. Fuel customers perform surveillance and QA audits of their vendors on an on-going basis to confirm that the vendors are performing in accordance with their QA programs. With NRC identifying time to breakaway oxidation as an important performance characteristic of the cladding, vendors would be responsible for establishing the time to breakaway oxidation for their cladding material and establishing production controls under their QA program to assure that the time to breakaway oxidation of manufactured cladding meets requirements.

Furthermore, 10 CFR 21 requires the reporting of defects and nonconformances that create a substantial safety hazard. Thus, existing regulations already require that vendors report defects that create a substantial safety hazard.

In summary, while it is important to perform tests to establish the time to breakaway oxidation, no new rules are needed. Regulatory guidance should establish that the time to breakaway oxidation should be addressed based upon current ECCS analysis spectra. This would assure that time to breakaway oxidation is established, controlled and evaluated. Existing regulations are adequate to assure that acceptable breakaway oxidation performance is maintained.

NRC Request for Comment 7a

The NRC requests comment on the testing frequency and sample size provided in the breakaway oxidation testing methodology (ADAMS Accession number ML090840258) and technical basis for the proposed breakaway oxidation testing requirement.

Westinghouse Comment 7a

Breakaway oxidation is a phenomenon that has been associated with clad ductility and therefore, it should be evaluated in assessing the performance of the fuel during a LOCA. Data presented in RIL 0801 show that alloy composition and manufacturing processes can impact the time it takes a particular cladding sample to achieve breakaway oxidation. However, the current data do not show that the small variations in alloy composition and manufacturing process parameters that are allowed during cladding fabrication have any significant impact on the time to breakaway oxidation.

As explained in the general response to item 7 above, there is no need for new regulations specifically requiring periodic testing to establish the time to breakaway oxidation for cladding. Identifying breakaway oxidation as an important performance characteristic of the clad in regulatory guidance associated with the rule is sufficient. The vendors' Quality Assurance programs, which comply with 10 CFR 50 Appendix B will assure that the cladding quality is controlled to meet breakaway oxidation time requirements.

Significant changes in alloy chemistry or in the manufacturing process would warrant an evaluation of the minimum time for the onset of breakaway oxidation. This evaluation would be done in accordance with the fuel vendor's Quality Assurance program.

With regard to the testing methodology, the proposed procedure for conducting breakaway oxidation tests of zirconium-based alloys does not identify the critical test parameters for establishing the minimum time for the onset of breakaway oxidation. Furthermore, Westinghouse test results do not support the statement in Section 5.1 of the draft procedure which states: "*For long-time isothermal tests, heating and cooling rates are not critical parameters.*"

Breakaway oxidation testing at Westinghouse has demonstrated heating rate to be an important test parameter in establishing the minimum time for the onset of breakaway oxidation. These tests show that a slower heating rate to the target isothermal test temperature results in significantly longer times for the onset of breakaway. Comparison of ZIRLO™ cladding specimens rapidly heated to temperature and slowly heated to temperature shows an earlier breakaway oxidation for the rapidly heated specimens. Both tests are consistent with the proposed test procedure but yield significantly different times for breakaway oxidation. The results were provided to NRC in LTR-NRC-09-24.

Due to the sensitivity of the results to heating rate, a technical basis is required for establishing a suitable heating rate (e.g., fast or slow) for breakaway oxidation testing. Small-break LOCAs can result in extended times at the lower oxidation temperatures that are relevant for breakaway oxidation. Therefore, heating rates for a small break LOCA (in the range of 2-5°F/sec) are most relevant. Westinghouse recommends that slower heating rates be used for establishing the minimum time for the onset of breakaway oxidation.

NRC Request for Comment 7b

Is there any ongoing or planned testing to further understand the sensitivity of breakaway oxidation to parameters controlled during the manufacturing process?

Westinghouse Comment 7b

Westinghouse has plans to further evaluate the sensitivity of breakaway oxidation to parameters controlled during the manufacturing process. This evaluation is intended to provide information on any inherent process sensitivities.

NRC Request for Comment 8

The NRC requests comment on the proposed concept that the reporting obligation in § 50.46 depend upon the margin to the relevant acceptance criteria. Please also comment on the specific approach to implement this objective as described under Objective 3 in Section III of this document.

Westinghouse Comment 8

The specific approach to implement this concept is overly burdensome, and adds cost with no apparent benefits from the perspective of the public's health and safety. The current approach has been successful in requiring plants with low PCT margins to report on a timely basis (annually, within 30 days, or under § 50.72 and 50.73). Additional regulatory burden is not warranted.

The application of the proposed specific approach for CP-ECR is not clear. One specific option would be to report changes in CP-ECR when the licensee is within 5% of the acceptance criterion. For example, if the appropriate criterion is 10% CP-ECR, reporting would not be required unless the change results in CP-ECR of 9.5% or higher.

It is further commented that in Section III the proposed oxidation tracking approach is based on CP-ECR. This is obviously to be consistent with the ANL data interpretation. To maintain that consistency, all evaluation models should use the Cathcart-Pawel model in all aspects of the calculation, including heat generation.

NRC Request for Comment 9

The NRC requests comment on the proposed concept of adding the results of breakaway oxidation susceptibility testing to the annual reporting requirement. Are there other implementation approaches that could help ensure that a zirconium-based alloy does not become more susceptible to breakaway during its manufacturing and production life-cycle?

Westinghouse Comment 9

Fuel cladding vendors perform testing to confirm that the product meets performance requirements. These tests are performed in accordance with the NRC-accepted vendors' Quality Assurance (QA) programs, which assure that product is produced in accordance with the alloy specification and qualified manufacturing process, and are auditable at any time by NRC. Vendors' Quality Assurance (QA) programs are sufficient; additional periodic data reporting to the NRC is not necessary.

Given that the need to account for the time to breakaway oxidation when licensing new cladding materials or implementing significant manufacturing process changes has been identified, vendors must qualify the new alloy or the manufacturing process changes to insure that the cladding meets the requirement for breakaway oxidation time. These qualifications are subject to audit by customers and by NRC.

NRC Request for Comment 10

The NRC requests comment on the proposed regulatory approach in which crud is required to be considered in ECCS evaluation models. If actual crud levels should exceed the levels considered in the evaluation model, the situation would be considered equivalent to discovering an error in the ECCS model. The licensee would then be subject to the reporting and corrective actions specified in § 50.46(a)(3) to resolve the discrepancy. The NRC also requests comment on the imposition of a requirement that one or more fuel assemblies be inspected at the end of each fuel cycle to demonstrate the validity of crud levels analyzed in the ECCS model.

Westinghouse Comment 10

As was pointed out in the ANPR, the NRC has already established regulatory review guidance that addresses the accumulation of crud and oxidation deposits on fuel cladding surfaces. This guidance is in review criteria in NUREG–0800, Section 4.2, "Fuel System Design," Section 4.3, "Nuclear Design," and Section 4.4, "Thermal and Hydraulic Design". Based on the review guidance, crud is already considered in fuel rod licensing calculations. Crud impacts on the LOCA event are in the calculation of the stored energy term. The phenomenological influences that should be included in the calculation of the stored energy are already expressed in this regulatory review guidance. There is no need to elevate crud above the other phenomena affecting stored energy by including it directly in the § 50.46 rule. This level of detail should be limited to regulatory guides.

For a significant and unexpected occurrence of crud that is observed during refueling operations, the impact of the crud on past and future operation of the affected fuel assemblies must be evaluated, including the impact on the LOCA analysis. Any need for reporting is already covered by existing regulatory requirements (e.g., §50.72 and 50.73).

The imposition of a requirement to inspect fuel assemblies at the end of each cycle has several negative impacts. It will increase outage times for many plants and increase doses to personnel at all sites. It will also require increased manpower and equipment resources. Additionally, the extra fuel handling for any internal rod extraction and examination increases risk for damage to the fuel.

NRC Request for Comment 11

What information exists to facilitate developing an acceptable crud deposition model that could correlate crud deposition with measured primary water coolant chemistry (e.g., iron-oxide concentration)? For boiling water reactors, it is difficult to perform visual inspections or poolside measurements of fuel rod crud thickness without first removing the channel box. A crud deposition model would facilitate the confirmation of design crud layers assumed in the ECCS evaluations and provide an indicator to reactor operators when crud levels approach unanalyzed conditions. Are there ongoing or planned industry efforts to monitor water coolant chemistry for comparison to observed crud deposition? If so, what amount of success has been obtained? Could a properly correlated crud model be sufficiently accurate to preclude the need for crud measurements at the end of each fuel cycle?

Westinghouse Comment 11

Isolated crud events have prompted the industry to expend considerable effort to understand the events, improve guidance for water chemistry, and raise awareness of operating and reload design good practices to reduce the likelihood of future crud events. Analytical models for crud development and transport have also been developed and validation to data has been undertaken. The current state-of-the art is that these analytical models are useful for trending and comparison purposes. Development work is continuing.

NRC Request for Comment 12

The U.S. commercial nuclear power industry claims that implementation of the proposed rule would be a significant burden in both money and resources. The industry has discussed an implementation cost of approximately $250 million.

Westinghouse Comment 12

The implementation cost estimate of approximately $250 million was based on consideration of a) expanded vendor database needs and b) combined vendor and licensee costs to update LOCA Evaluation Models, perform new design basis analyses, and the associated NRC review fees. Vendor database needs include hydrogen-charged ring-compression tests and expanded hot cell testing (at a minimum). Depending on the number of alloys the vendor provides or is developing, the adequacy of their existing databases, and the requirements for NRC review and approval, these costs are estimated to be on the order of $10 million per vendor.

The majority of the cost estimate was in the combined vendor and licensee costs to update LOCA Evaluation Models, perform new design basis analyses, and associated NRC review fees. It was expected that all LOCA Evaluation Models would need to be updated and re-licensed with the NRC. Each of the vendors currently maintains multiple LOCA Evaluation Models, and the costs to revise and re-license each of them with the NRC are expected to range from several hundred thousand dollars to $1M or more. There are currently 104 operating plants in the US. All of them are expected to need to update their licensing bases to reflect new small break/large break analyses with the new LOCA Evaluation Models. In addition to the analysis costs, there are additional costs involving preparation of plant-specific License Amendment Requests, NRC reviews, UFSAR and COLR revisions, and potential implementation of additional core surveillance requirements.

NRC Request for Comment 12a

What options are available to reduce this implementation cost?

Westinghouse Comment 12a

There are additional requirements proposed in the ANPR that were not previously anticipated and would increase costs even more. Examples include expanded break spectrum requirements, additional hot cell examinations to investigate asymmetric hydrogen distributions, poolside crud measurements during cycle outages, additional model development for hydrogen distributions and crud build-up, and the additional reporting requirements proposed for PCT, CP-ECR, breakaway oxidation, and crud. As noted in the prior comments, these additional proposed requirements are considered to be unnecessary.

One way to reduce the implementation costs would be to have staged implementation where any required reanalyses would be performed in conjunction with a planned plant change that would require a LOCA reanalysis. This staged implementation should begin after the industry has had time to develop and license Evaluation Models and analytical limits to account for the requirements of the final rule.

NRC Request for Comment 12b

Are there changes in core operating limits, fuel management, or cladding material that would reduce the cost and burden of implementing the proposed hydrogen based PQD criterion without negatively impacting operations?

Westinghouse Comment 12b

The proposed implementation has the potential to negatively impact core operating limits and fuel management strategies, without a commensurate increase in the public health and safety.

NRC Request for Comment 12c

A staged implementation would be more manageable for both the NRC and industry. One potential approach involves characterizing the plants based upon safety margin and deferring implementation for the licensees with the largest safety margin (e.g., lowest CP-ECR). The NRC requests comment on this implementation approach.

Westinghouse Comment 12c

A staged implementation is strongly endorsed. It is suggested that NRC and appropriate industry groups (for example, the PWR and BWR Owners Groups) work together to develop an appropriate strategy. As noted in Westinghouse Comment 12.a, implementation in conjunction with a planned plant change that would require a LOCA reanalysis would be one practical approach that would reduce regulatory burden.

Attachment 3
Westinghouse Comments on ANPR Appendices A and B
(Non-Proprietary)

Westinghouse Electric Company
P.O. Box 355
Pittsburgh, Pennsylvania 15230-0355

Clarification is requested regarding how the data points presented in Figure A will be used to develop PCT and ECR limits. It is also suggested that NRC provide a table specifying the reference and other pertinent information (e.g., cladding material, ECR, measure of ductility, etc.) for each data point in Figure A.

Figure A indicates that ductility was assessed using 2% offset strain, whereas Appendix B indicates that ductility may need to be assessed using 1% permanent strain. A consistent criterion should be used, or the basis for using the different criteria should be explained. Also, the flexibility recommended in Westinghouse Comment 6d in Attachment 2 should be built into the corresponding regulatory guidance.

Further clarification is requested regarding the concept of "applicability caveats" in the paragraph following Figure A.

Appendix B states that there is a need to consider the PQD database in Reference 1 (NUREG/CR-6967) in performing PQD tests for a new alloy. It is not clear what is meant by this. There would not be a need to reproduce the database. Based on an assumption that a new zirconium-based alloy would perform like other zirconium alloys as a function of hydrogen, the existing database would indicate the expected ductile to brittle transition. Most testing would then be performed in this area to confirm the expectation. The range of test conditions would be expanded only if that expectation was not met.

Attachment 4
Westinghouse Comments on PQD Testing Methodology Defined in ADAMS Accession number: ML090900841
(Non-Proprietary)

Westinghouse Electric Company
P.O. Box 355
Pittsburgh, Pennsylvania 15230-0355

The draft proposed cladding oxidation and PQD testing methodology provides guidelines for testing based upon the experimental techniques developed by ANL. The methodology specifies the test parameters that should be used without explicitly identifying test parameter requirements. Westinghouse recommends that parameters that are critical for obtaining relevant test results be clearly identified along with justification for the selected range. The reasons for this recommendation are two-fold:

1) Appendix B of the ANPR states that "PDQ testing . . . strictly adhere to the accepted experimental protocols . . .". Westinghouse recognizes the importance of maintaining consistency in testing techniques between testing laboratories in order to permit valid comparison of test results to the ANL database. In addition, clearly identifying the critical test parameters and their acceptable values will allow testing laboratories to demonstrate their strict adherence to the accepted protocols.
2) The methodology correctly allows departures from specified test parameters provided the changes are justified. However, the justification of several test parameters (e.g., heating rate, cooling rate, and quench temperature) is lacking while justification for steam flow rate is clearly stated. Westinghouse recommends that the justification of all critical test parameters be provided in the protocol in order to provide guidance to testing laboratories for developing justification for departure from the stated test parameters.

There are several examples in the proposed methodology that describe details of the testing performed at ANL without clearly stating the requirement. Westinghouse recommends that the methodology be separated into two parts. One part would present the test requirements that need to be met in order to 'strictly adhere' to the testing protocol. Additional information that is specific to a particular test facility (e.g., ANL's facility) would be provided in a subsequent section as an example of how the requirements could be met.

Quality assurance requirements are mentioned throughout the procedure. Westinghouse recommends that all quality requirements be consolidated in a single section so that all equipment requiring calibration are readily identified prior to initiation of testing. All testing of product at Westinghouse must be performed in accordance with the NRC-accepted Quality Assurance (QA) program, which assures that product is produced in accordance with the alloy specification and qualified manufacturing process, and is auditable at any time by the NRC. Westinghouse believes that vendors' Quality Assurance (QA) programs are sufficient and that additional periodic data reporting to the NRC of equipment calibration is not necessary.

Specific comments on the proposed methodology for oxidation and PDQ testing are provided below.

- Section 4.2 specifies a minimum sample length of 25 mm for two-sided oxidation with the maximum length no longer than the uniform temperature region of the furnace where uniform is defined as $<\pm 10^{\circ}C$ variation at the target temperature. This is inconsistent with Section 8.3 where the axial temperature variation should be $\leq 10^{\circ}C$. Section 8.3 also identifies a circumferential temperature variation of $\leq 20^{\circ}C$. It is not obvious why different temperature variations are specified for the axial and circumferential directions other than those were the values obtained in the ANL testing. Westinghouse requests that the test methodology clearly state the acceptable temperature variation that is allowed during the high temperature oxidation of test specimens.

- The sample configuration for one-sided oxidation tests is described as 75-mm long cladding specimens with welded end caps. Presumably, the end caps seal the inner diameter surface from steam to prevent oxidation. However, this configuration will result in pressurization of the specimen as the specimen is heated to the target oxidation temperature. It is noted that the one-sided oxidation tests reported in NUREG/CR-6967 utilized a 25-mm sample with no welded end caps. Westinghouse recommends that requirements for one-sided oxidation be stated and allow the testing laboratory to identify an appropriate sample configuration.
- Section 5.1 identifies one heat-up protocol for tests performed at 1200°C and a different heat-up protocol for tests performed at lower temperatures (e.g., 1100°C and 1000°C). In particular, tests performed at 1200°C are to be heated to 1000°C at a high rate (> 20°C/sec) and then at a slower rate (> 2°C/sec) to 1200°C to avoid overshooting the temperature. Heat up to lower temperatures is defined as >20°C/sec to within 100°C of the target followed by > 2°C/sec for the final 100°C. Since heat-up rate is more critical at the higher test temperatures (i.e., 1200°C), Westinghouse recommends that the heating rate defined for 1200°C be used for all temperatures.
- The last sentence in Section 5.3 should read "...<u>resistance</u> heating furnaces are acceptable...".)
- Section 6.1 specifies type S thermocouples. Westinghouse recommends that the use of other thermocouples (e.g., type K) as well as pyrometry be allowed as acceptable options for monitoring/controlling temperature provided their accuracy in measuring temperature can be demonstrated.
- The first paragraph of section 6.2 states that direct welding of TCs onto the outer surface of short (25-30 mm) oxidation samples is not recommended for data-generating tests. The rationale was that weld causes a local flaw and does not permit accurate post-test weight gain measurements. The second paragraph in section 6.2 appears contradictory as welding TCs onto longer oxidation samples is permitted for data generating tests and no mention was made of a possible impact on post-test weight measurements. Westinghouse requests clarification regarding the use of welded TCs on oxidation samples used for data generation.
- Westinghouse requests that attachment of thermocouples to the sample during thermal benchmarking include welding or strapping the TC to the outer surface. For resistance furnaces, strapped thermocouples adequately reflect the sample temperature due to the much more uniform temperature than achieved in radiant furnaces.
- Section 7.1 specifies the water quality to be Grade A with ≤ 45 ppb oxygen (ASTM G2). Grade A water does not imply low oxygen levels as the low oxygen levels are achieved by steaming or venting an autoclave prior to heating to temperature. Grade A is defined as having a pH of 5.0 to 8.0 and an electrical resistivity of not less than 1.0 MΩ-cm. In comparison, Type I water has a minimum resistivity of 18 MΩ-cm while Type II water has a minimum resistivity of 1.0 MΩ-cm. Westinghouse recommends that water quality be specified as Grade A or Type II with no requirement for steaming to achieve low oxygen levels. In

addition, no mention was made in NUREG/CR-6967 that the oxygen content in the water was ≤ 45 ppb oxygen.

- Westinghouse requests that steam flow rate may be determined from either the mass of water that is input to the system for steaming or the mass of condensed water that is collected on the exit side of the steam chamber. The average steam flow rate would remain in the range of 0.8 to 30 $mg/cm^2/sec$ as stated in section 7.2.
- Westinghouse experience is that zirconium-based alloys do not need to be protected from nickel and iron-based materials in a highly oxidizing environment. Westinghouse recommends that the section 8.1 be modified by stating that eutectic reactions between zirconium-based alloys and test train materials are not permitted. The protocol would allow the testing laboratory to decide the best method for meeting that requirement.
- Section 8.2 identifies a specific protocol for purging the steam chamber and stabilizing steam flow. The protocol may be suitable for tests that utilize radiant heaters for steam oxidation. Westinghouse recommends that the protocol be specified in terms of requirements rather than in terms of an acceptable technique. The requirements are the elimination of air from the steam chamber and establishment of a stable steam flow prior to ramping specimens to the test temperature. Requiring the samples to be heated to 300°C in a stable steam flow is incompatible with use of a resistance furnace in the Westinghouse facility. The protocol should permit heating of samples from room temperature or an intermediate (e.g., 300°C) to the target oxidation temperature.
- Section 8.4 specifies that steam flow is maintained until the sample temperature reaches 800°C. This is followed by a flow of water to quench the sample. The protocol needs to include an acceptable temperature range of the sample (e.g., 700°C-800°C) prior to immersing the sample in water. In the Westinghouse facility, steam flow is maintained during the entire quenching process as the sample is dropped into water. Some tolerance on the actual quench temperature is required, as it is not possible to confirm that sample temperature was 800°C when it entered the water.
- Section 8.5 provides equations for ECR. For completeness, Westinghouse recommends that the equation to be used for Wg in Equations 5 and 6 also be included in the section.
- Section 9.3 states that 'post-test hydrogen values should be corrected for weight gain so that the reference weight for hydrogen content is the pre-test weight.' Westinghouse recommends that details for performing the correction be clearly stated in the procedure.
- Section 10.1 specifies that nine additional PQD tests be performed over a narrow range of CP-ECR for as-fabricated cladding to establish the ductile-to-brittle transition. Westinghouse recommends that the number of tests be determined by the testing laboratory as ductility of as-fabricated cladding is not limiting.
- The first paragraph of section 10.2 provides much information that has little or no relevance to the testing methodology. To improve the clarity of the methodology, Westinghouse recommends that this paragraph be eliminated or included in a supplemental section of the protocol.
- Guidance is provided in section 10.2 on the likely embrittlement thresholds for prehydrided cladding. Westinghouse recommends that a table be included in this section that summaries the embrittlement threshold (i.e., CP-ECR) as a function of hydrogen content. The goal is to more clearly provide guidance on

selecting appropriate CP-ECR values for evaluation of ductility as a function of hydrogen content.

- Section 11.2 specifies a crosshead speed of 0.033 mm/sec (2 mm/min). Westinghouse requests that a tolerance for the crosshead speed be specified.
- Westinghouse recommends that section 12.1 include a comprehensive list of all results that are required in a data report. The current list is inconsistent with earlier sections of the procedure where additional items (e.g., steam flow rate) were identified for reporting. Westinghouse recommends that results not currently included in section 12.1 be deleted from reporting requirements.
- Section 12.1 specifies the test time from 300°C to the quench be reported. Westinghouse requests that the test time be defined as the time from the initial rapid temperature ramp to the quench as the initial sample temperature may not be 300°C.

Attachment 5
Westinghouse Comments on Breakaway Oxidation Testing Methodology Defined in ADAMS Accession Number: ML090840258
(Non-Proprietary)

Westinghouse Electric Company
P.O. Box 355
Pittsburgh, Pennsylvania 15230-0355

- Section 3.1 specifies that test samples be representative of tubing loaded in the reactor and contain one 'typical' scratch that extends along the sample length. Results from NUREG/CR-6967 show that scratches reduce the time for the onset of breakaway oxidation by about 200 seconds. Since the effect of scratches is small compared to the total time to breakaway oxidation, Westinghouse requests that an option of using non-scratched samples be allowed and the resulting breakaway time be reduced by 200 seconds to account for scratches.
- Section 6.3 specifies that Zry-2, Zry-4, and ZIRLO oxidized at 1000°C should be in good agreement with the CP correlation predictions. Westinghouse recommends that alloy specific references be deleted from the test procedure. Westinghouse agrees that sample weight gains should be compared to well-established vendor-generated databases.
- Section 7.1: As discussed in Westinghouse Attachment 4, Westinghouse recommends that water quality be specified as Grade A or Type II with no requirement for steaming to achieve low oxygen levels.
- Section 7.2: As mentioned in Westinghouse Attachment 4, Westinghouse requests that steam flow rate may be determined from either the mass of water that is input to the system for steaming or the mass of condensed water that is collected on the exit side of the steam chamber. Either method would be adequate to demonstrate that steam flow was maintained in the range of 0.5 to 30 $mg/cm^2/sec$.
- Section 8.1: As mentioned in Westinghouse Attachment 4, Westinghouse recommends that the testing laboratory be allowed to determine the appropriate method to prevent eutectic reactions between Zr-based alloys and the test train materials.
- Section 8.2 specifies a purging technique suitable for radiant furnaces. As mentioned in Westinghouse Attachment 4, Westinghouse requests that requirements be specified and allow the testing laboratory to determine the appropriate technique for meeting the requirements.
- Section 8.3 recommends that the heating time from 650°C to the target temperature be < 100 seconds. As discussed in Westinghouse Comment 7a in Attachment 2, breakaway oxidation times are dependent upon the heating rate. Westinghouse recommends that the testing methodology be changed to permit slower heating rates that are representative of the heating rates for a small break LOCA.
- The discussion of the characterization of two-sided oxidation samples in section 9.6 requires clarification. For the example cited, there was no breakaway oxidation on the outer diameter of the tube. According to section 9.3, no further characterization is required. It is not clear why metallographic examination of the sample would be performed when there is no visual evidence of breakaway oxidation on the outer surface.
- Section 10 on test temperatures needs to focus on the requirements rather than specifying how the requirement can be met. The requirement is to determine the minimum oxidation time in the temperature range of 950°C to 1050°C or to demonstrate the minimum time to breakaway is in excess of the maximum time above 1200°F (649°C) during a LOCA event. Testing for 5000 seconds as specified in section 10 may be excessively conservative if the maximum time above 1200°F (649°C) is significantly lower. Westinghouse recommends that the maximum test time specified in section 10 be determined and justified by the vendor. The protocol should not mandate the specific temperatures to be used

during the breakaway oxidation tests. Westinghouse recommends that the test temperatures cover the range from 950°C to 1050°C in temperature increments of 15°C to 20°C.

- If no breakaway oxidation is observed on the samples that are tested in the range of 950°C to 1050°C following exposure for the maximum time, Westinghouse recommends that no additional testing or characterization be required. Four additional confirmation tests at 1000°C appear arbitrary when there was no visual evidence of breakaway oxidation over the 100°C temperature range. Additional testing would be warranted if samples exhibited small local regions of 'non-black' oxide. In addition, requiring hydrogen measurements on samples exhibiting 'smooth and lustrous black' oxide is inconsistent with section 9.3 which states that no further characterization is needed. This is supported by testing at Westinghouse that shows < 200 ppm H for specimens with black oxide.
- The breakaway oxidation testing methodology presents several results from tests performed at Argonne National Laboratory (ANL) on ZIRLO cladding. Results include hydrogen pickup data in Figures 2 and 3 along with pictures of ZIRLO samples exhibiting breakaway oxidation in Appendices B and C. These results may not be representative of the breakaway behavior of ZIRLO as the heating rates were not prototypic of those during a small break LOCA. Westinghouse recommends that results included in the methodology be limited to test samples that were tested under representative conditions. It is noted that the testing at ANL did not evaluate the impact of heating rate on breakaway oxidation times and that full assessment of that experimental parameter should be considered prior to establishing a procedure for conducting breakaway oxidation tests.

Rulemaking Comments

From: Schueren, Paul [schuerp@westinghouse.com]
Sent: Tuesday, October 27, 2009 1:08 PM
To: Rulemaking Comments
Subject: LTR-NRC-09-51 Rev. 1, RIN 3150-AH42, Westinghouse Comments on the Advance Notice of Proposed Rulemaking on 10 CFR 50.46 Performance-Based Emergency Core Cooling System Acceptance Criteria (Non-proprietary)
Attachments: LTR-NRC-09-51-r1.pdf

Attached is LTR-NRC-09-51 Rev. 1 "RIN 3150-AH42, Westinghouse Comments on the Advance Notice of Proposed Rulemaking on 10 CFR 50.46 Performance-Based Emergency Core Cooling System Acceptance Criteria (Non-proprietary)"

The letter was revised to include RIN 3150-AH42 in the subject line.

Paul Schueren
Westinghouse Electric Company
schuerp@westinghouse.com

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To: "Rulemaking.Comments@nrc.gov" <Rulemaking.Comments@nrc.gov>
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