§ 50.46c ANPR and PRM-50-71 Comment Response Document

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This document contains all comments received, and the associated NRC responses, on the Advance Notice of Proposed Rulemaking published on August 13, 2009 (74 FR 40765; ADAMS Accession No. ML091250132). The NRC considered these comments when developing the 10 CFR 50.46c proposed rule.

This document also contains all comments received on petition for rulemaking (PRM) 50-71. This PRM was noticed in the Federal Register on May 31, 2000 (65 FR 34599). The NRC's determination to consider PRM-50-71 in the rulemaking process was published on November 6, 2008 (73 FR 66000). This document formally dispositions the comments received on the PRM. The NRC considered these comments when developing the 10 CFR 50.46c proposed rule.

This document places each public comment into one of the following categories:

General Comments Received on ANPR
Comments on ANPR Question 1
Comments on ANPR Question 2
Comments on ANPR Question 3
Comments on ANPR Question 4
Comments on ANPR Question 5
Comments on ANPR Question 6
Comments on ANPR Question 7
Comments on ANPR Questions 8 and 9
Comments on ANPR Question 10 and 11
Comments on ANPR Question 12
Comments on PRM-50-71

Within each category, the NRC has either repeated comments as written by the commenter, or summarized the comments for conciseness and clarity. At the end of the comment or comment summary, the NRC references the source of the comment.

§ 50.46c ANPR and PRM-50-71 Comment Response Document

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Comments Received on ANPR

Comment Number	Commenter	Affiliation	Abbreviation	ADAMS Accession No.
1	Herbert Feinroth	Ceramic Tubular Products, LLC	CTP	ML092800076
2	Ralph Meyer	Private Citizen	Meyer	ML092810032
3	Michael Billone	Argonne National Laboratory	ANL	ML092800345
4	Paul Schueren	Westinghouse Electric Company	Westinghouse	ML093030583
5	Gabor Salamon	Northern States Power Company	NSPM	ML043010561
6	Ken Heffner	Progress Energy	Progress	ML093010562
7	James Riley	Nuclear Energy Institute	NEI	ML093010564
8	Edwin Lyman	Union of Concerned Scientists	UCS	ML093010565
9	James Harrison	GE Hitachi Nuclear Energy Americas and Global Nuclear Fuels-Americas	GE	ML093020112
10	Jeffrey Reinhart	Omaha Public Power District	OPPD	ML093010566
11	Ronnie Gardner	AREVA NP, Inc.	AREVA	ML093020113
12	Zoltan Hozer	Hungarian Academy of Sciences, KFKI Atomic Energy Research Institute	AEKI	ML093070082
13	Ryamond Hruby	Indiana Michigan Power Company	I&M	ML093170211
14	D. Hooper	Strategic Teaming and Resource Sharing alliance	STARS	ML093170213
15	Mark Ajluni	Southern Nuclear Operating Company	SNC	ML093170215
16	Jeffrey Archie	South Carolina Electric & Gas Company	SCE&G	ML093210401
17	Jeffrey L. Hansen	Exelon Generation Company, LLC	Exelon	ML093230300
18	Jeffrie Keenan	PSEG Nuclear LLC	PSEG	ML093310326
19	Francois Barre	Institut de Radioprotection et de Sûreté Nucléaire	IRSN	ML093570269

Table 1. ANPR Comment Identification Key

General Comments on ANPR:

Comment: Substantive research to support modifications to the current ECCS acceptance criteria does not exist at this time. **(NEI-4, GEH/GNF-4, I&M-2)**

NRC Reponse: The NRC does not agree with this comment. The NRC believes that there exists sufficient data and understanding of cladding embrittlement phenomena to proceed with rulemaking. As documented in Research Information Letter (RIL)-0801 (ADAMS Accession No. ML090340073) and NUREG/CR-6967 (ADAMS Accession No. ML082130389), the empirical database supporting this rulemaking includes LOCA-type testing on as-fabricated, pre-hydrided, and irradiated segments of fuel rod cladding composed of several different zirconium-based alloys. When the technical basis was presented to the Advisory Committee on Reactor Safeguards (ACRS) in December 2008, the ACRS's December 18, 2008, letter to the Commission (ADAMS Accession No. ML083460310) concluded that "[t]here are sufficient data and understanding of the cladding embrittlement phenomena to justify and proceed with rulemaking."

Comment: The existing body of experimental data is ample justification for immediate action on a rulemaking, and a draft rule should be issued without further delay. The rule should provide sufficient margin to accommodate any uncertainties in the current experimental database. **(UCS-3)**

NRC Response: The NRC agrees with this comment, and is issuing a proposed rule. Further, the NRC agrees that the application of the rule should provide some margin to account for uncertainties in the experimental database, and this issue is more specifically addressed in draft regulatory guidance documents. The analytical limits on peak cladding temperature and time at elevated temperature are provided in draft regulatory guide (DG)-1263, "Establishing Analytical Limits for Zirconium-Based Alloy Cladding" (ADAMS Accession No. ML110871607). Guidance which outlines an NRC approved method for developing new analytical limits, accounts for uncertainty, repeatability, and variability within the measured parameters is provided in DG-1262, "Testing for Postquench Ductility" (ADAMS Accession No. ML110840283) The NRC is providing an opportunity for public comment on these regulatory guides as part of this 10 CFR 50.46c rulemaking.

Comment: Because the ANPR referenced a previous *Federal Register* notice published on July 31, 2008, that solicited comments on the adequacy of the technical basis for this rulemaking, the previously prepared responses to those comments should be available on this docket. **(Meyer-1)**

NRC Response: The NRC considers this comment to be out of scope, because the submittal is in regard to a previous *Federal Register* notice and not the ANPR.

The NRC also notes that the attachment to this ANPR comment submittal contains comment responses prepared by a former NRC employee for a *Federal Register* notice that solicited comments on the technical basis in July 2008. These responses were never made publicly-available nor reviewed and approved by NRC management. Therefore, the NRC does not consider the "comment responses" attached to this ANPR submittal to be an official agency position. However, the NRC does recognize the general technical relevance of the comments and will continue to consider the issues as appropriate.

Comment: General support of NEI's comment letter. **(NSPM-1, Progress-1, SNC-1, STARS-1, AREVA-1, Exelon-1, I&M-1)**

NRC Response: No response necessary.

Comment: General support of the comments made by the Nuclear Energy Institute and Westinghouse. **(OPPD-1, SCE&G-1)**

NRC Response: No response necessary.

Comment: General support the comments made by the Nuclear Energy Institute, Westinghouse, and GE Hitachi Nuclear Energy. **(PSEG-1)**

> **NRC Response**: No response necessary.

Comment: The current rule does not provide adequate protection against fuel cladding embrittlement because outdated technical information and assumptions supporting the current rule have been proven incorrect. **(UCS-1)**

> **NRC Response**: The NRC agrees with this comment and believes the proposed rule is necessary to ensure adequate protection to the public health and safety by restoring that level of protection (i.e., reasonable assurance of adequate protection) which the NRC thought would be achieved (throughout the entire term of licensed operation) by the current rule. The proposed rule language was developed to address the current regulation's inadequacies.

Comment: The NRC and industry assertion that there is no current safety risk has not been validated through plant-specific analyses, so the risk cannot be excluded. **(UCS-2)**

> **NRC Response**: The NRC agreed with this comment at the time the comment was submitted, and, in response to the research findings in RIL 0801, the NRC performed a preliminary safety assessment of currently operating reactors (ADAMS Accession No. ML090340073). This assessment found that, due to realistic fuel rod power history, measured cladding performance under LOCA conditions, and current analytical conservatisms, sufficient safety margin exists for operating reactors. Therefore, the NRC determined that immediate regulatory action was not required, and that changes to the ECCS acceptance criteria to account for these new findings can reasonably be addressed through the rulemaking process.
>
> Recognizing that finalization and implementation of the new ECCS requirements would take several years, the NRC decided that a more detailed safety assessment was necessary. As an alternative to a generic letter, the PWR Owners Group (ADAMS Accession No. ML11139A3090) and BWR Owners Group (ADAMS Accession No. ML1119501390), along with NEI, submitted ECCS margin assessment reports. After grouping plants based on similar design features, cladding alloys, or evaluation models and defining cladding alloy-specific analytical limits, the Owners Group (OG) reports identified analytical credits or performed new LOCA analyses necessary to demonstrate that the limiting plant within each grouping had positive margin relative to the research findings. The NRC conducted an audit of the OG reports and supporting GEH, AREVA, and Westinghouse engineering calculations. Based on the OG reports and supplemental information collected during the audits, the NRC was able to confirm, for every operating reactor, current safe operation. As documented in the audit report and safety assessment (ADAMS Accession No. ML12041A078), the NRC intends to verify, on an annual basis, continued safe operation until each licensee has implemented the new ECCS requirements.

Comment: Specific numerical ECCS acceptance criteria and implementation details should not be included in the rule, but rather in Regulatory Guides. **(Westinghouse-2)**

NRC Response: The NRC agrees with this comment. The proposed rule provides specific, objective, and enforceable performance requirements and acceptance criteria. Details on the development of NRC approved analytical limits which satisfy these performance requirements are documented in regulatory guidance documents.

Comment: The existing ECCS regulations include significant conservatism, and the new rule and regulatory guidance should not add excessive conservatism (e.g., by requiring bounding treatments of uncertainties with the new limits). **(Westinghouse-4)**

NRC Response: The NRC agrees with the comment. It is not the NRC's intention to create excessive new conservatisms with this rulemaking; however, the NRC must account for uncertainties that exist in the current database and uncertainties that may arise as a result of implementation (e.g., testing and data interpretation) of the rule. DG-1262 provides an NRC approved method for addressing uncertainty, repeatability, and variability in the development of analytical limits.

ANPR Question 1: "Objective 1 (to expand the applicability of § 50.46 to include any light-water reactor fuel cladding material) 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 alloy cladding material? 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?" (74 FR 40722)

Comment: Applicability should indeed be expanded to include the use of non-zirconium based cladding materials. **(CTP-1, NEI-1, GEH/GNF-1, Westinghouse-1)**

NRC Response: The NRC agrees with these comments. Provided the cladding material's behavior under LOCA conditions is adequately characterized and ECCS performance requirements and analytical limits are established which satisfy the general requirements in § 50.46c, an exemption to the regulations should not be necessary. The NRC does not, however, intend for this expansion to decrease the level of technical research and understanding needed to assure that ECCS systems can adequately perform their intended safety functions, maintain the core in a coolable geometry, limit the amount of combustible gases produced, and ensure long-term cooling following an accident. New performance-based criteria and analytical limits specific to a potential new group of cladding materials might later be established (e.g., instead of maintaining ductility via limits on ECR and PCT that are specific to zirconium-based alloys, there could be criteria that ensure a different figure of merit that is more applicable to the type of non-zirconium-based cladding material). The proposed rule language reflects the comment and is applicable to non-zirconium based cladding materials.

Comment: The ANPR's approach is proper; the three general conditions in 10 CFR 50.46(b) (coolable geometry, long term core cooling, and combustible gas generation) are appropriate for evaluating new materials. Another commenter pointed out that for an applicability expansion that would include non-zirconium claddings, it is unclear if preservation of cladding integrity would be explicitly required, as is accomplished by PCT and ECR criteria for zirconium-based claddings. **(CTP-2, NEI-1, AREVA-2, GEH/GNF-1, Westinghouse-1, IRSN-1)**

NRC Response: The NRC agrees that the three general criteria are appropriate for evaluating new cladding materials. However, because these general criteria do not, in and of themselves, provide specific and objective criteria by which a given material (and ECCS performance) can be technically evaluated, the NRC believes that development of a new material may require cladding-specific criteria to be established that ensure the three general criteria will be met. Fundamentally, specific criteria for a new material would correlate with that material's degradation mechanisms and behavior under LOCA conditions, much like ECR and PCT correlate to embrittlement and high temperature steam oxidation for zirconium-based claddings. It is anticipated that appropriate criteria for new materials would be revealed during testing to develop the new materials, and therefore this applicability expansion would simply alleviate the need for exemption requests to use a new material. The proposed performance-based criteria for zirconium-based alloys (and associated analytical limits) ensure that cladding ductility is maintained, but do not necessarily ensure cladding hermiticity (i.e., release of fission gas). Applications for future non-zirconium cladding materials may target criteria which ensure cladding integrity. But as with the proposed criteria, this is not sufficient to ensure a coolable geometry.

Comment: Such an applicability expansion would permit a relatively small proprietary data base for a new cladding material to be developed by a manufacturer, and this could allow a new cladding and any associated criteria to circumvent open scientific scrutiny which assures data base quality. **(ANL-1)**

NRC Response: The NRC agrees with the comment. The NRC recognizes the value of open scientific scrutiny in assuring database quality. Because a licensee would need NRC approval to use a new cladding material, and because a vendor (seeking NRC generic approval of the acceptability of the new cladding material) would need NRC approval of a topical report justifying the use of a new material, the NRC would have the opportunity to scrutinize the demonstrated performance of the new cladding material under normal and upset conditions, along with the supporting materials characterization, degradation mechanisms, mechanical testing database, and in-reactor experience. The NRC would expect an extensive empirical database supporting the new cladding material's in-reactor performance, in order to support any request for approval of the new cladding material.

Comment: The 50.46(b)(4) (coolable geometry) criterion should be made more quantitative to account for ballooning and flow blockage coolability issues related to high burnup fuel. **(IRSN-2)**

NRC Response: The NRC agrees with this comment. Ballooning and flow blockage impacts on core coolability are already considered in ECCS analyses. The NRC reviews these considerations as part of approving the ECCS evaluation models. To emphasize the importance of cladding ballooning, specific modeling requirements are specifically addressed in the regulatory guidance developed to support the rule.

ANPR Question 2: "The rulemaking objectives do not include expanding the applicability of § 50.46 to include fuel other than uranium oxide (UO_2) fuel. Is there any need for, or available information to justify, expanding the applicability of this rule to mixed oxide fuel rods?" (74 FR 40772)

Comment: 10 CFR 50.46(b) should not be limited to fuel types. One of the commenters also indicated that ballooning and fuel relocation phenomena will be influenced by fuel type. **(NEI-2, GEH/GNF-2, Westinghouse-12, IRSN-3)**

NRC Response: The NRC agrees with these comments. The proposed performance-based requirements for PQD and breakaway oxidation ensure that the fuel rod cladding does not behave in a manner which would impede core cooling. The cladding embrittlement mechanisms are well understood and the development of analytical limits on peak cladding temperature and time at elevated temperature (PQD and breakaway) are insensitive to uranium-oxide or uranium-plutonium mixed oxide fuel. The NRC recognizes that fuel pellet composition may influence the formation of a fuel bonding layer on the cladding inside surface. But this does not change the requirement that the potential effect of cladding ID oxygen ingress be considered in the evaluation model. The NRC recognizes that fuel pellet composition may also affect ballooning and fuel relocation phenomena. However, any potential effect of pellet composition on these two phenomena is beyond the scope of this rulemaking. As such, the specific performance requirements in the proposed rule have been expanded to include uranium-plutonium mixed oxide.

ANPR Question 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 break sizes and [nuclear steam supply system (NSSS)]/ECCS design combinations. This information may be used to set a specified minimum time to breakaway in the proposed rule's applicability statement." (74 FR 40772)

Comment: Instead of finding a minimum time to breakaway, a simple screening test for a specified time and temperature (e.g., 1000 °C) would be more compatible with the current level of understanding of breakaway oxidation. **(ANL-2)** Vendors should establish time to breakaway for each alloy and licensees will ensure that this time is greater than the time at temperature experienced during a small break loss-of-coolant accident (SBLOCA). **(NEI-3a, GEH/GNF-3a)**

NRC Response: The NRC agrees with the comments' suggestion that vendors should establish time to breakaway for each alloy and licenses will ensure that this time is greater than time at temperature experienced during a small break loss-of-coolant accident (SBLOCA). The NRC recognizes that both alloying composition and manufacturing process may influence the timing for the onset of breakaway oxidation. The NRC also recognizes that certain NSSS design and ECCS design combinations are more likely to experience a prolonged temperature excursion during a postulated SBLOCA. Therefore, it is equally important to establish an alloy-specific analytical limit on minimum time above a susceptible temperature and to evaluate each NSSS and ECCS design combination response to postulated SBLOCA. This approach ensures that a zirconium-based alloy susceptible to early breakaway oxidation is not matched with an NSSS/ECCS design which exhibits a prolonged temperature excursion. The NRC disagrees with the comment that, for finding a mininmum time to breakaway, a simple screening test for a specified time and temperature (e.g., 1000 °C) would be more compatability with the current level of understanding. The NRC does not consider the breakaway phenomenon to be understood to the degree necessary to eliminate consideration of temperature above and below 1000 °C.

Comment: Breakaway testing conducted at 649 °C is overly conservative. Testing at about 1000 °C is conservative and defensible. **(NEI-3b, GEH/GNF-3a)**

NRC Response: The NRC disagrees with these comments. Based on data reported by Leistikow and Schanz, zirconium alloys have been shown to be susceptible to the breakaway oxidation phenomenon at temperatures as low as 650 °C. Thus, time spent in steam at ≤650 °C was benign with regard to breakaway oxidation and hydrogen accumulation because of the very low oxidation rate. The NRC believes that there is not a sufficient understanding of the breakaway oxidation phenomenon to allow for new cladding alloys to be developed without testing to demonstrate the alloy's breakaway oxidation behavior as a function of temperature. Without hydrogen-accumulation data for temperatures between 650 °C and 800 °C, there is no basis for *not* including time spent at temperatures >650 °C in establishing the analytical limit for transient time. However, Draft Guide 1261 does establish an approach whereby periodic testing can be limited to a single temperature value once the temperature dependence of that alloy has been characterized to identify the temperature with the shortest time to breakaway.

Comment: Even with different manufacturing processes, breakaway oxidation at 800 °C will be very long and is not relevant. Since it is more relevant at 1000 °C, a threshold temperature set at 1650 °F (899 °C) would be appropriate without compromising safety. **(GEH/GNF-3c)**

NRC Response: The NRC disagrees with this comment. As stated above, the NRC believes that there is not a sufficient understanding of the breakaway oxidation phenomenon to allow for new cladding alloys to be developed without testing to demonstrate the alloy's breakaway oxidation behavior as a function of temperature. However, Draft Guide 1261 does establish an approach whereby periodic testing can be limited to a single temperature value once the temperature dependence of that alloy has been characterized to identify the temperature with the shortest time to breakaway. The NRC believes this provides adequate investigation of an alloy's breakaway oxidation behavior and an acceptable periodic confirmation that slight composition changes or manufacturing changes have not inadvertently altered the cladding's susceptibility to breakaway oxidation, without presenting unnecessary burden.

Comment: In most cases, the core will be returned to a quenched condition within 60 minutes of the initiation of the accident, but there are exceptions. Since it is not clear how this information will be used, further details will not be given. **(AREVA-4)**

NRC Response: The NRC accepts this comment, that without further details, information related to the maximum time span with cladding surface temperature above 1200 °F (649 °C) for the full range of piping break sizes and [nuclear steam supply system (NSSS)]/ECCS design combinations could not be provided. The question was intended to collect information to inform a universal time limit threshold for breakaway testing, thereby simplifying periodic testing requirements. As an alternative to a universal time limit threshold, Draft Guide 1261 establishes an approach whereby periodic testing can be limited to a single temperature. Draft Guide 1263 provides guidance for relating breakaway oxidation time to ECCS performance. The NRC believes that the combination of these two provisions simplifies periodic testing requirements consistent with our original intention and there is no longer a need for additional information related to the maximum time span with cladding surface temperature above 1200 °F (649 °C) for the full range of piping break sizes and [nuclear steam supply system (NSSS)]/ECCS design combinations.

Comment: Several commenters stated that the breakaway phenomenon should be considered relative to embrittlement. Specifically commenters stated:

- The ANPR proposes a breakaway criterion when 200 ppm hydrogen uptake is reached. This value is conservative relative to the hydrogen concentration when cladding embrittlement will occur, which is closer to 600 ppm. **(GEH/GNF-3b)**

- Breakaway should not be overemphasized because it does not automatically cause embrittlement. If breakaway happens before the cladding turns brittle, then the new criterion should not limit oxidation time since the cladding is still ductile. If breakaway happens after the brittle transition, then the time to breakaway is irrelevant. **(AEKI-3)**

NRC Response: The NRC agrees with the comment that embrittlement due to hydrogen may occur above 200 wppm hydrogen. However the limit of 200-wppm hydrogen pickup is suggested based on ANL's studies of breakaway oxidation as an indication of the onset of breakaway behavior, not loss of ductility. The NRC disagrees with the comment that breakaway oxidation should not be overemphasized. The proposed breakaway criterion was intended to supplement - rather than replace - the existing embrittlement criteria. If breakaway oxidation occurs, the embrittlement process is accelerated and the oxidation limits or time-at-temperature criteria are no longer completely sufficient to preclude embrittlement. A criterion based on the observance of cladding embrittlement may be non-conservative due to the rapid rate at which hydrogen is picked up once breakaway oxidation begins. Ductility is maintained for ≤435 wppm average hydrogen pickup. However, for high oxidation temperatures, the time needed to increase from 200 wppm to > 400 wppm hydrogen pickup could be as low as 100 seconds, which is well within the measurable uncertainty of the time required to initiate breakaway oxidation.

Comment: Information available in existing updated final safety analysis reports (UFSARs) concerning LOCA break scenarios (i.e., small break loss-of-coolant accidents (SBLOCA)) should be adequate to establish an NRC approved time to breakaway given the Appendix K conservatisms and the lack of consideration for operator actions. **(Westinghouse-9)**

> **NRC Response:** The NRC agrees in part with this comment. Existing SBLOCA evaluations under Appendix K to Part 50 do contain conservative assumptions. However, the NRC disagrees that the information in the UFSAR should be adequate to establish and NRC approved time to breakaway. The break spectrum analysis and initial conditions and assumptions in licensee UFSARs did not target time above a temperature susceptible to breakaway (i.e., 1200 °F (649 °C)). As such, the existing analyses may not have identified the limiting scenario. In addition, citing the conservatisms of Appendix K to Part 50 for this application is inconsistent with future plans to migrate toward best-estimate SBLOCA methods. Given the long duration prior to breakaway, the NRC agrees that reasonable operator actions, in accordance with existing Emergency Operating Procedures, may be permitted and would be approved on a case-by-case basis.

<u>**ANPR Question 4:**</u> "The NRC requests comment on two approaches to establishing analytical limits for cladding alloys, as described in Section III.2 of [the ANPR] and expand upon in the Appendices [of the ANPR], 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:

a. 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 [the ANPR].

b. 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?

c. Ring-compression tests conducted on cladding segments with identical hydrogen concentrations oxidized to the same Cathcart-Pawel – Equivalent Cladding Reacted (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." (74 FR 40772)

Comment: Both methods should be allowed. Plants with relatively low transient oxidation may opt for approach A, while plants with higher oxidation may want to reduce excess conservatism and utilize analytical limits based on more realistic test data. **(Westinghouse-3)** Another commenter also acknowledged support for both methods. However, that commenter stated that approach A should also provide allowable oxidation limits (CP-ECR versus hydrogen content) at lower peak oxidation temperatures (below 2200°F). **(Areva-5)**

NRC Response: The NRC agrees with these comments. The proposed rulemaking specifies performance-based requirements by 1) developing a Regulatory Guide with allowable CP-ECR versus cladding hydrogen embrittlement threshold at 2200 °F and 2) allowing licensees and vendors to conduct tests to develop unique analytical limits which satisfy performance-based requirements. However, there is an insufficient database to develop an embrittlement threshold at lower temperatures at this time.

Comment: The NRC should allow alternatives to ring compression testing (RCT) to determine post quench ductility (PQD). Alternative definitions cladding ductility be permitted and that future improvements in experimental techniques be allowed. **(Westinghouse – 15)** Experimental variability and data scatter may be overcome using alternative loading methods and geometries. **(NEI-7)**

NRC Response: The NRC agrees with these comments and agrees that there are multiple ways to define and demonstrate ductile and brittle behavior. The proposed rule would require that specified and NRC approved analytical limits on peak cladding temperature and time at elevated temperature be established which correspond to the measured ductile-to-brittle transition for the zirconium-alloy cladding material based upon an NRC approved experimental technique. The NRC has issued a draft regulatory guide which defines an NRC approved experimental technique. This experimental guidance addresses uncertainty, repeatability, and variability. However, applicants may elect to use an alternative experimental technique (which may include an alternative test or definition of ductility), but would have to demonstrate compliance under the proposed rule.

Comment: The new ductility criteria should not apply to the ballooned region and clad adjacent to this region. **(Westinghouse-7)**

NRC Response: The NRC disagrees with this comment. RIL-0801 discussed the applicability of new ductility criteria in the rupture region. Specifically, RIL-0801 stated that "no criteria have been found that would ensure ductility in the cladding balloon. However, loss of ductility in this short portion of a fuel rod should not lead to an uncoolable geometry as long as the amount of oxidation in the ballooned region remains limited in the current manner." Recently the NRC conducted additional testing of integral, as-fabricated and high burnup fuel and cladding materials which experienced heat up, ballooning, rupture and quench to characterize the mechanical behavior of ballooned and ruptured cladding. The research results and conclusions are documented in the report "Mechanical Behavior of Ballooned and Ruptured Cladding" (ADAMS Accession No. ML12048A475). This document serves as the regulatory basis for the treatment of the ballooned and ruptured regions in LOCA analysis. As documented in this report, the research results revealed that the mechanical properties in the rupture region, like in non-ruptured regions, degraded with increasing oxygen and hydrogen. The report concludes that when the new proposed ductility criteria is applied in the rupture region, mechanical properties in this region are maintained to that of fresh cladding at 17 percent CP-ECR. RIL-0801 has been supplemented to reference the regulatory basis report and the incorporate findings of the report (ADAMS Accession No. ML113050484).

Comment: In response to NRC solicitation for further PQD ring compression data, a vendor (Westinghouse) stated that it does not have any additional data, but cited the availability of restrained quench test results on cladding segments with hydrogen concentrations beyond 550 wppm. In addition, there is an ongoing industry test program will be testing pre-hydrided, unirradiated cladding beyond 550 wppm. **(Westinghouse – 13)** AREVA stated that it would be providing further experimental data generated at their laboratories in Saclay and Grenoble, France. **(Areva-7)** An industry group (NEI) further stated that the results of extensive research will be available by the middle of 2010. **(NEI-5)**

NRC Response: The NRC is aware of the available test results and ongoing experimentation. However, it does not appear that a significant source of additional PQD experimental data is available at this time to supplement the ANL database and assist the NRC in its development of a future Regulatory Guide. The public and industry will have the opportunity to comment on the generic analytical limits being used in draft Regulatory Guide DG 1263 – Regulatory Guidance on Establishing Analytical Limits (e.g., allowable CP-ECR versus cladding hydrogen embrittlement threshold at 2200 °F).

Comment: With respect to variability, repeatability, and statistical treatment, that existing LOCA methods and the requirement of maintaining clad ductility contained significant conservatism, and that those considerations are likely not warranted. **(NEI-7, Westinghouse-4)** The variability and uncertainty introduced by techniques and data interpretation performed by different entities could lead to significantly different results for the same data, especially for determining a ductile-brittle transition at 1 percent strain (referencing Figure 1 of the comment submission which shows a near horizontal branch in ECR around the 1 percent threshold). Based upon the difference in values obtained by ANL and RRC Kurchatov on the peer review process (referencing Figure 2 of the comment submission), the NRC should allow applicants to define their own cladding-specific limits. The commenter indicated that this would allow easier adoption of the rule at the international level in the future. **(IRSN-9)**

NRC Response: The NRC disagrees with these comments. In order to remove regulatory uncertainty in the review and approval of future test results, a standard approach needs to be developed. These standards need to address repeatability and variability in order to provide guidance on how many tests to perform. Otherwise, unnecessary tests resulting in wasted resources or an inadequate number of tests necessitating re-work may result. The public will have the opportunity to comment on the treatment of variability, repeatability, and uncertainty when conducting testing and developing analytical limits within DG-1262.

Conservatism in the LOCA models and methods may have been established to counter various uncertainties (e.g., initial conditions, break flow, etc). Measured experimental data on cladding residual ductility is unrelated to plant operating conditions, system capacities, and performance, or LOCA models. Further, it is difficult to track conservatism, which may or may not exist in each plant's LOCA analyses.

The NRC recognizes that LOCA related phenomena may be ranked differently and regulatory criteria may vary among the international regulatory agencies. The proposed rule and supporting regulatory guides would provide the ECCS performance requirements along with an NRC approved set of analytical limits and experimental technique for its application. The proposed rule was written to regulate facilities within the United States, and was not developed to regulate international facilities.

Comment: The NRC should provide further clarification regarding how data presented in Figure A of the ANPR will be used to develop analytical limits within a future RG. In addition, future RGs should allow alternative definitions of cladding ductility. **(Westinghouse-20a)**

NRC Response: The information presented in the ANPR, based on the ANL developed database, will be used to define a generic zirconium-cladding oxidation limit as a function of hydrogen absorbed. It will be necessary for each zirconium-based alloy to provide a model representative of the hydrogen absorbed versus burnup. The combination will then be used to define the allowable oxidation as a function of burnup.

The public and industry have the opportunity to comment on the generic analytical limits contained in DG-1263 (i.e., allowable CP-ECR versus cladding hydrogen embrittlement threshold at 2200 °F).

Comment: The NRC should provide further clarification regarding how the existing irradiated PQD database will be considered in the development of analytical limits for future cladding alloys. **(Westinghouse-20b)** If revised analytical limits were generated by an applicant, the experimental procedures should be shown to produce CP-ECR limits at 2200 °F that were lower than the limit established based on the extensive ANL PQD database. **(ANL-5)**

NRC Response: DG-1263 is issued along with the proposed rule which defines "specified and NRC approved analytical limits" based on the existing database. This database is quite extensive (includes as-fabricated, pre-hydrided, and irradiated cladding specimens) and has received peer review. The DG identifies any requirements necessary to demonstrate the continued applicability of these analytical limits to future alloys. The NRC intends to issue standardized experimental techniques it finds acceptable for defining ductile-to-brittle transition.

Comment: In a later interpretation of several of the ANL RCT test specimens, cladding hydrogen content was revised. This later report indicates ductility was maintained in samples with approximately 600 wppm after 4 percent CP-ECR.**(ANL-6)**

NRC Response: The NRC is issuing DG-1263 with this proposed rule which sets forth the analytical limits, and clear citations indicating the source of all data and information.

Comment: Significant effort has been spent in developing a ductile-to-brittle transition based upon the raw data that appears in Figure A of the ANPR. Further, some of the data in Figure A is outdated and newer data is available. There is a risk associated with less experienced individuals using their judgement to determine an embrittlement threshold from either the existing ANL raw data or results from future PQD test programs. **(ANL-8a, 8b)**

NRC Response: The NRC agrees with these comments. The NRC is issuing DG-1263 with this proposed rule which defines "specified and NRC approved analytical limits" based on the existing database. This database is quite extensive (includes as-fabricated, pre-hydrided, and irradiated cladding specimens) and has received peer review. The NRC is also issuing DG-1262, which provides an NRC approved experimental technique to developing alternative analytical limits. This experimental guidance will minimize the likelihood of improper data interpretation.

Comment: Results from future PQD testing on new, as-fabricated zirconium-based alloys should fall within 18-20 percent CP-ECR (embrittlement threshold) and that any deviation is more likely due to test condition and data interpretation than alloy composition. **(ANL-9a)**

NRC Response: The NRC does not agree with this comment, and is issuing DG-1262 which provides an NRC approved experimental technique to developing alternative analytical limits. This experimental guidance would provide an approach that minimizes the likelihood of improper data interpretation.

Comment: The inclusion of a cladding ID oxygen source requirement is premature. Any requirement should be placed in regulatory guidance (flexible implementation document) so that as the science solidifies, the treatment of the potential phenomena can be kept appropriate. **(Areva – 8)**

NRC Response: The NRC disagrees with this comment. Recognizing that the onset of a fuel/clad bonding layer is dependent on several factors, the proposed rule would specify an analytical requirement to treat this potential ID oxygen source in the calculation of CP-ECR, if it exists. The proposed rule would not prescribe the exact onset of the fuel/clad bonding layer. Compliance with the analytical requirement in the proposed rule for a given fuel rod design would be part of the NRC's review/approval of the LOCA analysis methods.

Comment: One commenter did not generally oppose the performance-based aspects of the conceptual approach to the rule presented in the ANPR. However, with respect to Approach B, a very high standard must be met for the quality of the technical basis supporting such deviation requests, with respect to standardization of experimental protocols, reproducibility of results, and peer review.**(UCS-4)**

NRC Response: The NRC agrees with this comment. DG-1263 is issued along with the proposed rule which defines "specified and NRC approved analytical limits" based on the existing database. This database is quite extensive (includes as-fabricated, pre-hydrided, and irradiated cladding specimens) and has received peer review. In addition, DG-1262 is issued along with the proposed rule which provides an NRC approved experimental technique to developing alternative analytical limits. This experimental guidance will address uncertainty, repeatability, and variability. However, applicants may elect to use an alternative experimental technique (which may include an alternative test or definition of ductility) but must demonstrate compliance with the rule.

ANPR Question 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.

a. The NRC requests information on the size and depth of the current hot-cell 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.

b. 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 maximum asymmetric hydrogen concentration is aligned with the maximum stress point or in pre-hydrided material by introducing asymmetric distribution during hydriding. The NRC requests comment on these or other methods to treat asymmetric hydrogen distribution." (74 FR 40772)

Comment: In response to NRC solicitation for information on the size and depth of the cladding hydrogen measurement database, two commenters cited recent technical papers from the 2009 Top Fuel Conference. **(Westinghouse-22, NEI-24)**

NRC Response: The technical papers cited in the comments illustrate that the extent of industry's hydrogen database is limited in depth, especially in its ability to segregate the sensitivity of each cladding alloy to each external factor and to quantify the level of uncertainty.

Comment: With respect to variability of cladding hydrogen content and its potential effects on PQD ring compression tests, existing LOCA methods and the requirement of maintaining clad ductility contain significant conservatism and that these considerations are likely not warranted. **(Westinghouse-4)**

NRC Response: The NRC disagrees with this comment. In order to remove regulatory uncertainty in the review and approval of future test results, hydrogen uptake models, and LOCA analyses, a standard approach needs to be developed. These standards need to address repeatability and variability in PQD RCT results, variability and asymmetry in hydrogen measurements, and the confidence level needed in predicting cladding hydrogen content. Conservatisms in the LOCA models and methods have been established to counter various uncertainties (e.g. initial conditions, break flow, etc) and are unrelated to the experimental technique for measuring residual ductility.

Comment: Hot cell examination of non-failed fuel rods has not identified asymmetric hydrogen ditribution around the circumference of fuel cladding. The asymmetric hydrogen concentrations measured in the post-LOCA test samples do not correlate with hydrogen analyses on untested fuel rods. As such, the use of average hydrogen values in the development of hydrogen uptake models and implementation of the new rule would be adequate. **(NEI-8)**

> **NRC Response:** The NRC disagrees with this comment. Insufficient data exists to support the assertion that ANL hydrogen measurements which indicated asymmetric hydrogen concentration do not represent current hydrogen characteristics. Asymmetric hydrogen concentration was observed in measurements both pre- and post-LOCA testing.

Comment: Metallurgical examinations of high burnup Zircaloy-2 do not indicate any circumferential or radial asymmetric hydrogen distributions. As such, there is no basis for GEH/GNF to include hydrogen variability in the development of hydrogen models or consider such non-uniformities as part of this rulemaking. **(GEH/GNF-5b)**

> **NRC Response:** The NRC disagrees with the comments. Cladding composition and fabrication process will influence hydrogen uptake and hydride distribution. Alloy-specific and perhaps even process-specific hydrogen models, and the treatment of uncertainties in the application of those models, may be necessary. In order to remove regulatory uncertainty in the review and approval of future test results, hydrogen uptake models, and LOCA analyses, a standard approach needs to be developed. These standards need to address repeatability and variability in PQD RCT results, variability and asymmetry in hydrogen measurements, and the confidence level needed in predicting cladding hydrogen content.

Comment: Large azimuthal and axial variations in hydrogen content were seen repeatedly in specimens taken from real fuel rods with average hydrogen content greater than 400 wppm. Therefore, some statistical treatment of a large data base is warranted in the development of a hydrogen uptake model. With regard to RCT, five data points at each oxidation level would be sufficient to characterize the embrittlement threshold for cladding with large azimuthal variation in hydrogen content. **(ANL-7)**

> **NRC Response:** The NRC agrees with the comment that some statistical treatment of a large database is warranted in the development of a hydrogen uptake model. DG-1262 recommends nine repeat tests to address repeatability of PQD measurements. The statistical treatment of variability in corrosion related hydrogen pick-up may be handled more appropriately through the cladding-specific hydrogen uptake models. The NRC is currently determining how to address asymmetric hydrogen distributions in the reactor when performing PQD tests on pre-hydrided specimens.

Comment: For pre-hydrided and high-burnup rings with large azimuthal variations in hydrogen content, measured offset and permanent strains showed expected variation dependent on the orientation of the maximum hydrogen content relative to the locations of maximum stress. Thus, scatter in the RCT data is more related to non-uniform hydrogen distribution. **(ANL-7)**

NRC Response: The NRC agrees with this comment; orientation of the maximum hydrogen content relative to the locations of maximum stress has an effect on the scatter in the RCT data. Repeat tests are recommended to identify this scatter. The statistical treatment of azimuthal variability in corrosion related hydrogen pick-up may be handled more appropriately through the cladding specific hydrogen uptake models.

Comment: A reasonable approach is cladding average hydrogen concentration over several pellet heights. Ensuring the cladding at the average hydrogen concentrations should ensure an over all ductile material with spot embrittlement. **(Areva-6)**

NRC Response: The NRC disagrees with the concept of localized embrittlement. Exactly how hydride asymmetric distribution is combined with variability in the PQD test database is provided in DG-1262. The public has the opportunity to comment on these details during the public comment period associated with the draft regulatory guide.

<u>**ANPR Question 6:**</u> "A draft proposed cladding oxidation and PQD testing methodology is provided at ADAMS Accession No. ML090900841.

a. 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.

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

c. 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-based 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.

d. 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." (74 FR 40773)

Comment: The "1.00 percent" ductility measure described in the ANPR should be changed to "1.0 percent" due to measurement uncertainty. **(ANL-3a)**

NRC Response: The NRC agrees with the commenter's statement. It is consistent with the test procedure and is adjusted accordingly in the proposed rule.

Comment: The ≥ 1.0 percent permanent strain criterion is endorsed **(ANL-3b, NEI-12, GEH/GNF-6d)**

NRC Response: The NRC agrees with the commenter's statement. It is consistent with the test procedure and is adjusted accordingly.

Comment: Several commenters made statements regarding the definition of demonstration of ductility provided in the ANPR. Speficially commenters stated:

- Instead of defining a specific parameter for ductility such as 1 percent permanent strain, brittle vs. ductile behavior should be determined by the characteristics of a load-displacement curve. **(AEKI-1)**

- An accurate and reliable measurement of permanent strain depends on skill and experience in sample preparation, proper conduct of testing, in stopping tests at the correct time, and in data assessment and interpretation. The issue of accounting for these factors and therefore ensuring data quality hasn't been adequately addressed. **(ANL-3c)**

- Alloy composition was observed to produce less variability on strain values than the variability observed for the same alloy using different manufacturing methods. ANL believes that embrittlement of new, as-fabricated, dilute zirconium-based alloys would occur within the narrow range of 18-20 percent oxidation. Any data that may fall outside this range would be more likely due to test conditions and data interpretation rather than alloy composition. **(ANL-9a)**

- The PQD testing methodology referenced in the ANPR is overly prescriptive and restrictive. A more flexible methodology is reasonable because results can be compared to the existing database. **(NEI-9, GEH/GNF-6a, Westinghouse-8)**

- The testing methodology for ductility should not be prescriptive, but only specify the test objective and the accuracy of determination to allow for improvements in testing methods or in the basic science involved. **(AREVA-7)**

- Why would the proposed rule favor a permanent strain criterion rather than an offset strain criterion? **(IRSN-8)**

- Alternate definitions of cladding ductility should be permitted with the intent to find techniques that reduce data scatter, represent actual post-LOCA loading conditions, and may provide consistent results between laboratories. **(Westinghouse-15)**

NRC Response: The NRC agrees that there are multiple ways to define and demonstrate ductile and brittle behavior. The criteria were designed to be as specific and enforceable as possible, while maintaining the agency's focus on developing performance-based regulations. One of the purposes of the ANPR was to engage stakeholders in balancing specific and enforceable criteria with performance-based regulations. The commenters' suggestions will be considered when weighing these two purposes as the agency moves forward with development of final regulatory guidance.

Comment: Ductility should be measured at room temperature instead of 135 °C because after a LOCA the core will be cooled to room temperature. 135 °C is not conservative. **(AEKI-2)**

NRC Response: The NRC disagrees with this comment. The selection of the appropriate test temperature for conducting ring compression testing was considered as the experimental program was developed. The NRC continues to maintain the position outlined by the Commissioners in the ECCS hearings of 1973, that retention of ductility is the best guarantee against potential fragmentation of fuel cladding under various types of not-so-well-quantified loading, such as thermal shock, hydraulic, and seismic forces. The United States Atomic Energy Commission (USAEC) believed that quench loads were likely the major loads, and, therefore, the test temperature was selected to demonstrate ductility at the time of reflood and quench. The NRC agrees with the concept that brittle materials can retain strength. However, a strength-based criterion requires detailed knowledge and interpretation of cladding loading conditions which result from a LOCA.

Comment: Vendors should have the option to determine embrittlement threshold for as-fabricated cladding alloys. **(ANL-9b)**

NRC Response: The NRC agrees with the commenter's statement and encourages additional testing on the part of the industry. DG-1262 and DG-1263 were developed to support vendor supported testing and embrittlement thresholds.

Comment: PQD data generated to date supports the validity of using a pre-hydrided surrogate. **(ANL-10, NEI-11, GEH/GNF-6d)**

NRC Response: The NRC disagrees with this comment. The NRC recognizes PQD data for pre-hydrided material appear consistent with PQD data for irradiated material at the same pre-transient hydrogen content. However, the consistency has not been demonstrated with one-to-one comparisons of pre-hydrided material and irradiated material at the same hydrogen content. The NRC's current position is that without such direct comparisons, it is not appropriate to eliminate the need to demonstrate PQD performance with irradiated material.

Comment: Industry intends to set a range of test conditions based on testing efforts completed or currently under way. In this way, the industry hopes to create a standard ASTM test procedure within two years. **(NEI-10, GEH/GNF-6d)**

NRC Response: The NRC supports industry efforts to develop an ASTM test procedure. Until this test procedure is completed, the NRC is providing test procedures in DG 1262 which are acceptable.

Comment: With regard to the PQD procedure, alloy-specific references should be removed. Weight gains for all alloys should be compared to CP or vendor-supplied databases. **(Westinghouse-14a)**

NRC Response: The NRC will consider the comment's request to remove alloy-specific references where they are not required for understanding. The NRC interprets the commenter's second statement as agreement with the approach specified within the test procedures, since the test procedures states, "the oxidation level is defined as the equivalent cladding reacted (ECR) calculated using the Cathcart-Pawel (CP) weight gain correlation."

Comment: Several commenters provided comments on the test procedures for conducting PQD and breakaway testing which were referenced in the ANPR.

- Detailed comments, including section-by-section comments, were provided for the draft PQD testing methodology. **(Westinghouse-14b)**

- Detailed comments, including section-by-section comments, were provided for the draft breakaway oxidation testing methodology. **(Westinghouse-21)**

- Ambiguities in sections 11.1 and 11.3 of the PQD procedure should be fixed. **(GEH/GNF-6c)**

NRC Response: The NRC acknowledges the commenter's detailed review of the document. The objective of disseminating and requesting comments on the NRC approved test procedures was to allow stakeholders to request additional clarity or specifications where they felt it was necessary. The NRC has made a number of changes to address the comment requested information and clarity in a revised procedure. In addition, the NRC developed draft guidance to describe the use of the test procedure provides additional information and clarity.

Comment: Many details in both the PQD and breakaway testing procedures can be handled by vendor QA programs that comply with Appendix B and Part 21. Specifically, use of a qualified certification lab should be allowed. **(GEH/GNF-6b)**

NRC Response: The NRC interprets this comment as a statement by the commenter that PQD and breakaway performance could be incorporated into Appendix B to Part 21, rather than within § 50.46 itself. The NRC disagrees with this comment. This suggestion was considered in the development of the proposed rule language, and was not determined to be sufficient for addressing the phenomenon which could challenge the susceptibility of fuel rods to embrittlement during a LOCA.

Comment: Many countries have gone away from using a ductility-based criterion. Ring compression tests for ductility are far more severe than actual LOCA conditions would impose on the cladding. Strength-based testing, such as that performed by Japan, is more realistic, and some of their samples that survived quench tests were subsequently subjected to ring compression, and almost all resulted in brittle failure, thus implying that a brittle cladding could survive a LOCA, and therefore ductility is not the best measure.

Further, strength-based quench tests do not predetermine the failure location like ring compression tests do, but this limits identification of failure conditions (e.g., wall thinning, oxidation, and secondary hydriding). **(IRSN-5)**

NRC Response: The NRC disagrees with this comment. The NRC agrees with the concept that brittle materials can retain strength. However, a strength-based criteria requires detailed knowledge and interpretation of loading which actual LOCA conditions would impose on the cladding. The NRC continues to maintain the position outlined by the Commissioners in the ECCS hearings of 1973, - that retention of ductility is the best guarantee against potential fragmentation of fuel cladding under various types of not-so-well-quantified loading, such as thermal shock, hydraulic, and seismic forces.

Comment: The influence of hydrogen content on ductile-brittle transition is a problem for the balloon/burst region. An embrittlement extrapolation would put zero CP-ECR at about 800 wppm, yet about 2000 wppm would be expected in the balloon. Thus it would be difficult to apply a ductility criterion to this region. However, it has been observed in bending tests or quench constrained tests on ballooned and burst rods that the failure location was near the burst mid-plane where hydrogen concentration is low. **(IRSN-6)**

NRC Response: The NRC understands the commenter's suggestion – that the intersection of the ductile-to-brittle transition with zero-CP-ECR would imply the point at which hydrogen alone is assumed to lead to embrittlement. However, no such extrapolation is being suggested at this time. It should be clarified that the influence of hydrogen content on the ductile-brittle transition as described in the ANPR is made in reference to the hydrogen content of the cladding before experiencing a LOCA transient. The 2000 wppm expected in the rupture region cited in the commenter's statement refers to hydrogen that is absorbed during the LOCA transient.

Comment: A requirement to use Cathcart-Pawel may introduce some confusion if comparisons are made to previous oxidation limits obtained with Baker-Just. Further, comparison of measured ECRs to CP calculated values might reinforce the erroneous idea that local oxidation is the parameter that controls cladding embrittlement when in reality it is oxygen diffusion in the base metal that causes embrittlement. IRSN would favor an alternative parameter related to the oxygen profile in the base metal, and IRSN is currently working to develop such a parameter. **(IRSN-7)**

NRC Response: The NRC agrees with the comment's suggestion that providing additional clarification would be useful to compare oxidation limits using Cathcart-Pawel, rather than Baker-Just equations. In addition the NRC agrees with the statement that it is oxygen diffusion in the base metal that causes embrittlement, rather than local oxidation. However, the NRC believes the best parameter to preclude embrittlement is the calculated oxidation because the Catchcart-Pawl equation considers both time and temperature and accounts for the rate of oxidation diffusion into the base metal indirectly. These clarifications are included in the proposed rule's statement of considerations.

Comment: Embrittlement criteria should be derived from two kinds of tests based on behavior during a LOCA. If ballooning and burst don't occur, then mechanical tests (e.g., ring compression) should be applied. If ballooning cannot be excluded, the criteria should be based on tests that address embrittlement due to ballooning and secondary hydriding. **(AEKI-4)**

> **NRC Response:** The NRC disagrees with this comment. The NRC has completed research to further investigate the rupture phenomenon and its effect on fuel cladding integrity and mechanical performance. Fuel fragmentation and relocation phenomena are also planned for further research. The NRC is actively participating in and following the results of many LOCA-related experimental programs including those at the Halden Reactor Project and the QUENCH program. The scope of the current rulemaking effort is not intended to encompass these phenomena and is instead based on the PQD and breakaway testing research documented in NUREG/CR-6967.

ANPR Question 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.

a. The NRC requests comment on the testing frequency and sample size provided in the breakaway oxidation testing methodology (ADAMS Accession No. ML090840258) and technical basis for the proposed breakaway oxidation testing requirement.

b. Is there any ongoing or planned testing to further understand the sensitivity of breakaway oxidation to parameters controlled during the manufacturing process?" (74 FR 40773)

Comment: Periodic testing for breakaway oxidation should be required. This phenomenon could be affected by manufacturing process changes. **(ANL-11, UCS-5)**

> **NRC Response:** The NRC agrees with this comment. Any fuel rod which experiences breakaway oxidation during a postulated LOCA will rapidly become brittle and more susceptible to gross failure, and would no longer be in compliance with the requirement for coolable core geometry in 10 CFR Part 50, Appendix A, Criterion 35. The NRC added a requirement for such periodic testing for breakaway as part of the proposed § 50.46c rulemaking.

Comment: Additional requirements for breakaway testing, including reports, are not needed because existing regulations (10 CFR 50 Appendix B (Quality Assurance) and 10 CFR 21 (vendor defect reporting)) are adequate to assure acceptable breakaway oxidation performance is maintained. **(NEI-13, GEH/GNF-7 and 9, Westinghouse-10)**

NRC Response: The NRC interprets these comments as claiming that there is a sufficient tool to address this type of cladding performance measure within current regulations. The NRC disagrees with these comments. Neither Appendix B to Part 50 nor Part 21 specifically require the successful performance in testing designed to investigate the susceptibility to early breakaway oxidation. However, the suggestion that breakaway performance could be incorporated into Appendix B to Part 50 and Part 21, rather than within proposed § 50.46c itself was considered in the development of the proposed rule language, and the NRC concluded that it was insufficient for addressing the phenomenon which could challenge the susceptibility of fuel rods to embrittlement during a LOCA.

Comment: Regulatory guidance should establish that time to breakaway should be addressed based on current ECCS analysis spectra. Since performance characteristics are controlled under QA and Part 21, and because small variations in alloy composition and manufacturing process parameters don't have a significant impact, breakaway phenomena can be controlled without any new regulations. **(Westinghouse-16)**

NRC Response: The NRC disagrees with this comment. The NRC wishes to clarify that the research program indicated that small variations in alloy composition and manufacturing process parameters were shown to have a significant impact on breakaway phenomenon. As such, the proposed rule would require periodic testing and reporting to confirm the established alloy-specific breakaway oxidation analytical limits.

Comment: A test program is underway to attempt to isolate impurities that may be responsible for short breakaway oxidation times. **(NEI-14)**

NRC Response: The NRC encourages the experimental efforts of an industry-sponsored testing program related to breakaway oxidation.

Comment: The draft breakaway procedure does not establish critical test parameters. Further, and contrary to the procedure, heating rate has a significant effect on breakaway in that a slower rate increases the time to onset of breakaway. Since SBLOCAs result in extended times at lower temperatures, a slower heating rate is recommended. **(Westinghouse-17)**

NRC Response: The NRC's objective of disseminating and requesting comments on the test procedures was to allow stakeholders the opportunity to request additional clarity or specifications where they felt it was necessary. The NRC acknowledges the commenter's detailed review of the document. The experimental procedures provided in DG-1261, "Conducting Periodic Testing for Breakaway Oxidation Behavior" (ADAMS Accession No. ML110840089) and DG-1262 have been revised from the versions published for public comment in the ANPR, and address many of the comments received in response to the ANPR. Some of the comments were addressed by indicating where specifications are recommendations intended to prevent early breakaway oxidation due to experimental artifacts.

Comment: Westinghouse plans to further evaluate the sensitivity of breakaway to parameters controlled during the manufacturing process. **(Westinghouse-18)**

NRC Response: The NRC encourages the experimental efforts of an industry-sponsored testing program related to breakaway oxidation.

Comment: Searching for a minimum time to breakaway down to 649 °C is unnecessary. Research (Leistikow and Schanz) indicates that a simple screening test for a sufficiently conservative specified oxidation time at 1000 °C is sufficient. Lower temperatures would yield far longer breakaway times than any SBLOCA transient could achieve. **(IRSN-4)**

NRC Response: The NRC agrees with this comment. The NRC wishes to clarify that the request for information related to the maximum time span with cladding surface temperature above 1200 °F (649 °C) for all NSSS/ECCS design combinations was intended to inform a specified time criteria for a given temperature. It was envisioned that demonstration of NRC approved performance (i.e., no indication of breakaway behavior) at a specified temperature for a specified time would provide a straightforward, simple pass/fail test that would be far less burdensome to fuel vendors than a full suite of tests within the full range of temperatures feasible in a LOCA scenario. The appropriate requirement for a minimum time without indication of breakaway for such a test must be informed by LOCA calculations.

ANPR Questions 8 and 9: "The NRC requests comment on the proposed concept that the reporting obligation in § 50.46 depend on 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 [the ANPR].

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?" (74 FR 40773)

Comment: A graded approach for reporting PCT temperatures greater than 2090 °F should not be included in the rule. The existing 50 °F change threshold is sufficient. **(NEI-15a, GEH/GNF-8, Westinghouse-5a, PSEG-2)**

Comment: The NRC should indeed increase the reporting threshold for PCTs less than 2090 °F to be for changes or errors of 100 °F or more. **(NEI-15b, Progress-3, GEH/GNF-9, GEH/GNF-8, Westinghouse-5b, PSEG-2)**

Comment: The reporting requirement for CP-ECR should not be as described in the ANPR, but rather when the CP-ECR exceeds 95 percent of its limit. **(NEI-16, GEH/GNF-8, Westinghouse-5c, GEHGNF-9)**

Comment: All evaluation models should use the Cathcart-Pawel model in all aspects of the calculation, including heat generation, to maintain consistency. **(Westinghouse-5d)**

Comment: NRC inquiry on issues that may impact compliance with 10 CFR 50.46 can be conducted in real time by NRC resident inspectors, therefore any additional written reports required under this rule would be a burden with no corresponding safety benefit. **(Progress-2)**

Comment: The CP-ECR should only require reporting when the limit is approached and not be based on incremental changes from previous analyses. **(Progress-4)**

Comment: New reporting requirements associated with equivalent cladding reacted (ECR) based on Cathcart-Pawel (CP) and breakaway oxidation are unclear. **(PSEG-3)**

Comment: If cladding material or design change substantially, different reporting criteria could be in order. Therefore, reporting requirements should be maintained in NRC documents other than the CFR so they can be kept current more easily. Further, reporting requirements should only be for changes which would degrade the margin to criteria if applied individually to the analysis of record. **(AREVA-3)**

Comment: None of the proposed reporting requirements should be included. **(STARS-4**

NRC Response: The NRC disagrees with these comments. The NRC is sympathetic to the point that the use of CP for both ECR and heat generation would simplify analytical methods; however, doing so would require a change in Appendix K to Part 50. Such a change would necessitate changes in all existing, approved Appendix K methodologies, review and approval of the changes, and re-analyses of all plants for which Appendix K LOCA analyses form their licensing basis.

Reporting requirements for changes in evaluation models, whether error corrections or methodology improvements, have been a part of § 50.46 since its inception. The current requirement is based on a sum of the absolute values of the changes. The NRC will not propose changing the format of the reporting requirement on peak cladding temperature. However, due to the importance of the relationship between embrittlement and exposure, the NRC is proposing an additional reporting requirement related to change in predicted oxidation that is structured in a manner similar to the peak cladding temperature reporting requirement.

The NRC is open to considering alternate limit values than those proposed. The NRC views the values for the size of the reporting windows for the peak cladding temperature and equivalent cladding reacted to be points for further discussion and welcomes specific proposals from the stakeholders.

<u>ANPR Questions 10 and 11:</u> "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 action process 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.

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." (74 FR 40773)

Comment: The current ECCS regulations in § 50.46 do not need to be revised to require that crud be accounted for in ECCS analyses because: **(Westinghouse-11a, STARS-3b, NEI-17, PSEG-5)**

(1) Existing industry guidelines to perform a crud and cladding risk assessment for each fuel cycle provide sufficient assurance that crud levels will not be detrimental to fuel performance;
(2) Industry has implemented good practices for water chemistry, complies with water quality guidelines and performs crud and corrosion risk assessments for each reload cycle; occurrences of significant crud buildup are atypical events such that including a regulatory requirement for crud inspections each cycle is not appropriate;
(2) Existing NRC review guidance in NUREG-0800 ensures that licensees will properly address crud in ECCS analyses; and
(3) The NRC must review and approve all licensee ECCS analysis models, thus the NRC reviewer can ensure that each model properly addresses the effects of crud on ECCS performance.

NRC Response: The NRC disagrees with the comments' assertions that the existence of industry guidelines, NRC guidance, and the NRC review and approval process eliminates the need for additional rulemaking to address the potential impact of crud deposits on reactor fuel cladding. Compliance with either industry or NRC guidance is not a binding or enforceable requirement. When the NRC reviews ECCS models and new reactor fuel designs, a reviewer may only ensure that the proposed design complies with legal requirements. Ambiguity now exists in the NRC regulations regarding the requirements for licensees to address crud deposits on reactor fuel for the duration of each fuel cycle. The NRC believes that the regulations should be amended to clarify that considering the effects of crud on reactor fuel performance throughout each fuel cycle is an enforceable requirement. The NRC is proposing to add a requirement that would clearly specify that crud deposition during reactor operation must be considered in ECCS models. The NRC believes that a flexible assessment process could be established in which the degree of consideration of the effects of crud would increase as the calculated margin to the ECCS analysis acceptance criteria decreases. Should any unanticipated crud levels be discovered at a facility, the licensee would be required to ensure that calculated ECCS performance continues to meet the acceptance criteria.

Comment: A requirement to perform crud inspections after each fuel cycle should not be included in the rule because industry guidelines, NUREG-0800 guidance and the NRC review and approval process effectively address the crud issue, making additional rulemaking unnecessary. **(NEI-17, Westinghouse-11a, Westinghouse-11b)**

Periodic inspections to determine crud levels should not be required by reasoning that had an inspection had been performed in the fuel cycles before the crud events at the specific BWR referenced in PRM-50-84, those inspections would not have revealed abnormal crud buildup and would have provided no advanced information on crud buildup during the following cycles.

Furthermore, imposing a requirement to inspect fuel assemblies for crud at the end of each fuel cycle would increase outage times at many plants and increase radiation doses to personnel at all sites. It would also require increased manpower and equipment resources. Additionally, the extra fuel handling for any internal rod extraction and examination would increase the risk of damage to the fuel. **(GEH/GNF-10, Westinghouse-11d)**

NRC Response: The NRC agrees that fuel inspection requirements should not be imposed. However, sufficient operating data must be available to establish a high-confidence design basis crud level for a given reactor. Crud models should be based on trends in measured crud deposits and potential impacts of changes in operating parameters and chemistry must be considered when defining the design basis crud level for upcoming cycles.

Comment: Analytical models for crud development and transport have been developed and validation of data is underway. Currently these models are useful for trending and comparison purposes. Additional development work is in progress. It is premature to apply these models for licensing basis purposes. **(NEI-18, GEH/GNF-11, Westinghouse-11e)**

NRC Response: The NRC agrees with the comments that crud models cannot be used by all licensing basis purposes. However, licensees who have such models would have the option to use them as appropriate in performing the crud deposition risk assessment discussed.

Comment: There doesn't appear to be a connection between the subject of crud and the proposed LOCA regulations. **(NEI-19, GEH/GNF11)**

NRC Response: The NRC agrees with the comments that there is no direct relationship between the subject of crud and the anticipated new ECCS acceptance criteria requirements. However, when resolving PRM-50-84, the NRC decided to consider promulgating new regulations addressing the effects of fuel crud deposits on ECCS performance. For resource efficiency, the NRC is combining these regulatory changes into a single rulemaking effort.

Comment: Existing regulations require that when a significant and unexpected occurrence of crud is observed during refueling operations, the impact of the crud on past and future operation of the affected fuel assemblies 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). **(Westinghouse-11c)**

NRC Response: The NRC does not agree with this comment. If a severe crud event occurred at a facility such that the analyzed consequences of the crud levels would exceed the § 50.46(b) acceptance criteria, reporting to the NRC in an 8-hour report would be required under § 50.72(v) and submittal of a licensee event report (LER) would be required under § 50.73(v). However, if the analyzed consequences of a crud event greatly reduced the margin to the § 50.46(b) acceptance criteria but did not exceed the acceptance criteria, reporting to the NRC would not be required under §§ 50.72 or 50.73.

The current § 50.46(a)(3)(iii) requires licensees to report to the NRC whenever changes to or errors in ECCS models affect the calculated temperature, even if the newly calculated temperature continues to meet the acceptance criteria. The timeliness of the reporting depends on the magnitude of the calculated change. Since the proposed rule would specify that the effects of crud must be considered in ECCS models, if unanticipated or unanalyzed levels of crud are discovered, then the licensee must determine if correct consideration of crud levels would result in a reportable condition as provided in the relevant reporting paragraphs.

Comment: The proposed rulemaking requires additional crud monitoring such as inspections every refueling outage. This requirement is unnecessary since some licensees, who had observed development of crud layer in the past, have already established crud prevention and protection programs which implement adequate core design and operational chemistry controls. These licensees have also confirmed their crud models by verification inspections during outages following the occurrence of crud formation. Thus, provided an accurate and adequate crud model and established prevention program exists, crud monitoring does not increase the defense-in-depth, and an exemption should be granted to these licensees with regard to additional crud monitoring. **(STARS-3a)**

NRC Response: The NRC agrees with the comment that requirements for additional crud monitoring should not be imposed on licensees. Licensees who have developed and confirmed crud models by verification inspections during outages following occurrences of crud formation may continue to use these models to comply with the requirements in the proposed rule.

Comment: NRC should not move forward with a “risk-informed” 10 CFR 50.46a rule before the § 50.46c rule is completed. **(UCS-7)**

NRC Response: The NRC disagrees with the comment. The NRC has proposed, and the Commission has approved, a schedule in which the § 50.46a risk-informed ECCS rule is independent of the § 50.46c rule. However, in an August 10, 2007 memorandum, the Commission directed that if license amendment applications under § 50.46a are submitted before the final § 50.46c rule is completed, the NRC review of those applications "should ensure an appropriate safety margin for fuel clad integrity that will have high assurance of meeting the final acceptance criteria." The NRC notes that the schedule for the § 50.46c rule is delayed.

ANPR Question 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 (NRC-2008-0332-008.1 at http://www.regulations.gov).

a. What options are available to reduce this implementation cost?

b. 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?

c. 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 calculated CP-ECR). The NRC requests comment on this implementation approach." (74 FR 40773)

Comment: Implementation costs could be reduced if, because the NRC will have already reviewed and approved revised LOCA Evaluation Models, the NRC does not review the results of the application of those LOCA Evaluation Models. **(NEI-20, GEH/GNF-12a, NEI-23, GEH/GNF-12a)**

NRC Response: The NRC does not agree with this comment. The NRC must review and approve the plant-specific LOCA analyses since it is the individual plant that is obligated to comply with § 50.46. Review and approval of the LOCA Evaluation Models simplifies and expedites that review and approval process.

Comment: Implementation costs could be reduced if NRC does not require licensees to specifically determine the most limiting LOCA break scenario for breakaway oxidation. Many plants have LOCA break spectrum analysis results in their UFSAR that make it obvious that there is a very large margin to the regulatory limit, and this should be sufficient justification. However, this is not appropriate for all plants, and some will still need to determine the most limiting scenario. **(NEI-21) (GEH/GNF-12a)**

NRC Response: The NRC agrees that certain NSSS/ECCS designs are more vulnerable to extended time at elevated temperature during certain postulated LOCA scenarios. Hence, these plants would be more susceptible to breakaway oxidation if they employed a cladding alloy with worse breakaway performance (i.e., shorter time to onset of breakaway). Licensees will be required to justify the limiting LOCA scenario with respect to breakaway performance requirements. The NRC agrees that the effort required to demonstrate conformance to this requirement may vary depending on NSSS/ECCS specific margin. Applicants will be judged on a case-by-case basis.

Comment: The need for a staged implementation process would be lessened if the NRC agrees to a streamlined process outlined in comments NEI-20 and NEI-21. **(NEI-23, GEH/GNF-12a)**

NRC Response: The NRC disagrees with these comments. No response necessary, inasmuch as the NRC does not agree with the process suggested in NEI-20 and NEI-21. See responses to NEI-20 and NEI-21 above.

Comment: A staged implementation approach should not be used. **(UCS-6)**

NRC Response: The NRC disagrees with this comment. Based upon limited resources both in the industry to develop models and perform plant-specific LOCA analyses and within the NRC to perform reviews, a staged implementation is the most practical approach. Additionally, the NRC's preliminary safety assessment of currently operating reactors (ADAMS Accession No. ML090340073) found that due to realistic fuel rod power history, measured cladding performance under LOCA conditions, and current analytical conservatisms, sufficient safety margin exists for operating reactors. This was confirmed in the NRC's audit of plant specific information provided by the BWR and PWR owners groups. Therefore, the staged implementation plan is a safe option.

Comment: Implementation costs could be reduced if the complexity of hydrogen pickup models, as referred to in question 5 of the ANPR, was reduced. A similar case exists for crud buildup models. **(GEH/GNF-12b)**

NRC Response: The NRC disagrees with the comment. At this time, the NRC is not aware of a method of properly accounting for the effects of fuel burnup other than through an alloy-specific hydrogen uptake model. The alternatives at this time are to use a NRC defined ECR vs burnup curve or to develop a hydrogen uptake model based on hydrogen absorption vs burnup for specific alloys being used in the core.

Comment: To the extent that a facility's Tech Specs do not list a specific revision of the evaluation model topical report(s), a separate submittal should not be required. **(Progress-5)**

NRC Response: The NRC disagrees with the comment. While the licensee may not be required to submit a license amendment request updating the COLR list of references, the new LOCA analysis-of-record which employs the new model would need to be submitted for NRC review.

Comment: Compliance with the rule change should depend on the facility and their fuel design and operating strategy. The implementation phase should give licensees two fuel operating cycles after the NRC approves the vendor methodology changes. **(Progress-6, Westinghouse-6)**

NRC Response: The NRC has developed a three track implementation approach to reduce the burden of implementing this rule on both the NRC and industry. Nuclear power plants are grouped into one of these three tracks based on the number of steps required to demonstrate compliance with the proposed rule and each track has a distinct implementation time frame related to this level of effort. Using this approach, licensees in the third track would be required to fully comply with the new requirements by 5 years after the effective date of the rule. Since the level of effort required to demonstrate compliance depends on the available safety margin, a consistent schedule such as recommended in this comment response (e.g., two refueling cycles) is not appropriate. (See Section V.E, "Implementation," of the *Federal Register* notice for a more detailed description.)

Comment: A staged implementation process that doesn't require licensees to submit a new LOCA analysis until the submittal is required for a plant change may be reasonable. This approach would be supported by the understanding that safety margins are adequate. **(NEI-22, GEH/GNF-12a, Westinghouse-19b)**

NRC Response: The NRC agrees with the comments' statement that a staged implementation process is reasonable, but disagrees that the new LOCA analysis should be required to be submitted when such a submittal is required for a plant change. The NRC has developed a three track implementation approach to reduce the burden of implementing this rule on both the NRC and industry. Nuclear power plants are grouped into one of these three tracks based on the number of steps required to demonstrate compliance with the proposed rule and each track has a distinct implementation time frame related to this level of effort. Using this approach, licensees in the third track would be required to fully comply with the new requirements by 5 years after the effective date of the rule. (See Section V.E, "Implementation," of the *Federal Register* notice for a more detailed description.) Track 1 plants have demonstrated through the BWR/PWR Owners Groups reports and audit that they do not require new ECCS evaluations. Track 2 and Track 3 plants will require a new ECCS evaluation, including adopting a previously approved realistic evaluation model, revisions to existing evaluation models, new LOCA break spectrum analysis, multiple rod survey, and Technical Specification or core operating limit report (COLR) changes. Additional information on the proposed implementation plan is available in the statement of considerations.

Comment: The timeline and cost for the proposed implementation will need to account for NRC review and approval of vendor LOCA models, along with all licensee applications potentially requiring NRC required review. A staged implementation approach should include the NRC working with the respsective BWR and PWR owner's groups. **(PSEG-4)**

NRC Response: The NRC agrees with this comment. The proposed rule's regulatory analysis accounts for NRC review and approval of vendor LOCA models, among other items which require NRC review. The NRC created the proposed staged implementation plan using information obtained from the BWR and PWR Owner Groups' reports.

Comment: Implementation costs could be kept from increasing by not including unnecessary requirements such as: expanded break spectrum requirements, additional hot cell exams for asymmetric hydrogen distribution, poolside crud measurements, and additional reporting requirements. **(Westinghouse-19a)**

NRC Response: The NRC disagrees with the suggested implementation approaches. Expanded break spectrum analyses are necessary to identify the NSSS/ECCS susceptibility to prolonged high temperature excursions for evaluating breakaway oxidation. Hot cell examinations are necessary to develop high confidence hydrogen uptake models (especially for alloys with large hydrogen concentrations). Poolside measurements may be necessary for plants prone to crud. Additional annual reporting of breakaway is necessary to confirm cladding performance and detect inadvertent changes.

Comment: The proposed implementation has the potential to negatively impact core operating limits and fuel management strategies. **(Westinghouse-19c)**

NRC Response: The NRC disagrees with the comment that the proposed implementation would negatively impact core operating limits and fuel management strategies. Rather, implementation of the proposed rule would increase safety margin by requiring operation consistent with new research.

Comment: The proposed rulemaking will force licensees with LOCA PCTs close to the limit and high ECRs to re-evaluate with a Best Estimate Method instead of the current Appendix K method. This will cause licensees to incur significant expenses and the need to divert resources could impact safety. An exemption should therefore be granted to licensees with a conservative Appendix K analysis of record. **(STARS-2)**

NRC Response: The NRC does not agree that an exemption should be granted to those plants currently evaluated under the Appendix K option of § 50.46. The proposed rule will still provide for either the realistic evaluation with determination of uncertainty or an evaluation compliant with the requirements of Appendix K to 10 CFR Part 50. Irrespective of the evaluation methodology adopted, the plant analysis must conform with the stated acceptance criteria.

Commenters on PRM-50-71

Comment Number	Commenter	Affiliation	Abbreviation	ADAMS Accession No.
1	Mark J. Burzynski	TVA	TVA	ML003737324
2	James F. Mallay	Siemens Power Corporation	SPC	ML003739180
3	John R. Caves	Carolina Power and Light Company	CPL	ML003741304
4	David J. Modeen	Nuclear Energy Institute	NEI	ML003741474
5	Fawn Shillinglaw	Private Citizen	FS	ML003741855
6	R.E. Grazio	Florida Power Corporation	FPC	ML003741883
7	James A. Hutton	PECO Nuclear	PECO	ML003743627
8	R.M. Krich	ComEd	COMED	ML003643559
9	Angela K. Krainik	Arizona Public Service Company	APS	ML003743806
10	Stephen A. Byrne	South Carolina Electric and Gas Company	SCEG	ML003752459
11	Bob Leyse	Private Citizen	BL	ML013180072

Table 2. PRM-50-71 Comment Identification Key

Comment: Five commenters supported PRM-50-71. **(TVA-1, SPC-1, CPL-1, NEI-1, APS-1)**

NRC Response: No response necessary.

Comment: The proposed change should be promulgated in a direct final rulemaking. **(SPC-3, CPL-3, NEI-2, COMED-2)**

NRC Response: The NRC disagrees with these comments. Direct final rules are only used for actions that are minor or administrative in nature, and not likely to receive significant adverse public comment. The NRC does not regard the rulemaking sought by the petitioner to be minor, nor unlikely to result in significant adverse public comment. Therefore, the rulemaking sought by this PRM will be accomplished using the notice and comment rulemaking procedure in the Administrative Procedure Act.

Comment: The proposed § 50.46(e) should be written to read: “Approved cylindrical zirconium-based alloys are those whose performance has been evaluated and for which NRC has concluded that the acceptance criteria of paragraphs § 50.46(b)(1) and (b)(2) apply.” **(NEI-3, TVA-1, SPC-2, CPL-2, FPC-1, COMED-1)**

NRC Response: The NRC agrees in general with the concept of these comments. However, the NRC has prepared a more comprehensive rewrite of the regulation to establish the performance-based acceptance criteria for fuel design, and the performance-based acceptance criteria for the ECCS.

Comment: Cladding materials should be long-term tested because material interaction is a major concern in the areas of dry cask storage, transportation of spent fuel, and disposal. The commenter also requested information on how the use of new cladding material would affect dry cask storage, transportation, and disposal. **(FS-1, FS-17, FS-9, FS-6)**

NRC Response: The NRC considers this comment to be beyond the scope of PRM-50-71 because the comments address the performance of the fuel assembly in a storage cask; whereas the focus of PRM-50-71 (and the 10 CFR 50.46c rulemaking) is on the performance of fuel in the reactor. The NRC will forward the comment to the appropriate group within the NRC for consideration.

Comment: The petitioner should have fully stated § 50.46(b)(1) and (b)(2), as opposed to referencing the paragraph numbers. The public should not have to go to the library to determine the criteria found in those paragraphs. The NRC should not state the petitioner's request verbatim, and should also provide clarifying material to the public. **(FS-2, FS-3)**

NRC Response: The NRC disagrees with the comments indicating that the petitioner should have fully stated § 50.46(b)(1) and (b)(2), as opposed to referencing the paragraph numbers. Nothing in 10 CFR 2.802 requires a petition for rulemaking to fully state the text of relevant regulations. Nor does the NRC regard it as an undue burden for a member of the public to perform some research to obtain the language of relevant NRC regulations. There are many ways to obtain access to the text of NRC regulations; for example, the NRC's website provides the text for all NRC regulations.

The NRC disagrees with the comments that the NRC should not state a petitioner's request verbatim. The NRC often states the petitioner's request verbatim so that the NRC is not accused of misrepresenting the petitioner's submittal.

The NRC does not know what the comments means by "clarifying information." Hence, the NRC is not providing a response to this portion of the comments.

Comment: Petitions for rulemaking should not be noticed under the "proposed rule" category because doing so misleads the public and is confusing. **(FS-4)**

NRC Response: The NRC considers this comment to be outside the scope of this rulemaking. The comment addresses one aspect of the NRC's generic procedures for rulemaking petitions. As such the comment is not relevant to the substance of PRM-50-71 or the (50.46c rulemaking).

The NRC acknowledges the perspective in this comment. However, the *Federal Register* has three categories: Notices, Proposed Rules, and Final Rules. Because petitions for rulemaking are a request for rulemaking action, and request a proposed change to an existing rule, they are filed under the "Proposed Rule" category.

Comment: The NRC should provide information regarding NEI's membership, specifically whether it included cask vendors, fuel vendors, and fuel fabrication facilities. **(FS-5)**

NRC Response: This inquiry should be directed to the Nuclear Energy Institute (NEI).

Comment: The NRC should provide information on how variations in the systems of each facility impact the use of new claddings. **(FS-7, FS-9)**

NRC Response: Cladding materials are tested and analyzed in such a way as to envelope the range of operating parameters that may be encountered in the licensed facilities that use the material. In addition, and to ensure that the cladding material is appropriate for use in the specific facility, each licensee must submit an analysis of record that includes all affected accidents and transients prior to loading the fuel and using the new material in the core. The NRC then reviews and approves each analysis of record.

Comment: The petition's proposal could enhance efficiency, but that enhanced efficiency would be in exchange for less oversight of public health and safety by the NRC. **(FS-8, FS-15)**

NRC Response: The NRC disagrees with these comments. The petition's proposal would remove specific zirconium-alloy names from the regulation. Doing so would not eliminate the need for NRC review and approval of specific zirconium-alloys for use as reactor fuel cladding. The proposed rule contains a requirement that no fuel can be loaded into a reactor unless the licensee either determines that the fuel meets the requirements of paragraph (d) or complies with technical specification governing lead test assemblies. Elimination of the alloy-specific names and inclusion this requirement enhances efficiency by eliminating the need for exemptions to use cladding alloys other than those named, while maintaining oversight of public health and safety by requiring the use of NRC approved fuel in the reactor.

Comment: The NRC should provide information regarding how close the new cladding materials would be to the limit, and stated that "under the limit" is different than "ALARA" with respect to minimizing exposure to workers. **(FS-10)**

NRC Response: "Under the limit," as referred to in this comment and the proposed rule, pertains to ECCS performance. Thus, the limits with respect to cladding performance, are unrelated to ALARA, which is used in 10 CFR Part 20 and 10 CFR Part 100 to limit radiation doses to humans.

Comment: BWR plants have more corrosion concerns than PWR plants; this is another reason why site specific cladding evaluations should be required. **(FS-11)**

NRC Response: The NRC agrees with the observation in this comment, that the BWRs have greater corrosion concerns as compared with PWRs. However, the NRC disagrees that "site specific" cladding evaluations must be required by the rule. In order to account for the effects of corrosion in PWRs and BWRs, and in response to PRM-50-84, the proposed rule would amend Appendix K to Part 50 to explicitly require that the steady-state temperature distribution and stored energy in the reactor fuel at the onset of the postulated LOCA be calculated by factoring in the role that the thermal resistance of crud deposits and/or oxide layers plays in increasing the stored energy in the fuel. These requirements also need to apply to any NRC-approved, best-estimate ECCS evaluation models used in lieu of Appendix K to Part 50 calculations. Therefore, BWR plants will account for the effects of site specific corrosion in their LOCA analyses.

Comment: The NRC should provide information on, and results of, testing of Alloy A, M5, and duplex alloys, and BWR plants. **(FS-12)**

NRC Response: The NRC agrees in general that the information provided to the NRC on these tests should be publicly-available (unless they are proprietary). Testing was conducted on a wide array of current commercial zirconium cladding alloys including ZIRLO™, M5, Zircaloy-2, and Zircaloy-4, and the empirical database for these cladding materials (supporting this rulemaking) is documented in NUREG/CR-6967 and RIL-0801. . However, Alloy A and duplex alloys were not part of this investigation and the NRC is not aware of their use in current reloads.

Comment: The NRC should provide information on whether it approves lead test assembly procedures before they occur. The results of these tests should be released, and a lessons learned program be implemented. **(FS-13)**

NRC Response: The NRC disagrees with the comment in part. The NRC has requested specific comment on the use of lead test and lead use assemblies in the proposed rule's statement of considerations. The NRC also notes that the detailed information and test results gathered during the lead test and use assembly programs are proprietary to the fuel vendor conducting the tests. The NRC cannot publicly release those results, but does review the results during the application for approval for use of the fuel assembly design. No change was made to the proposed rule as a result of the comment.

Comment: Heating and quenching a cladding material is not adequate testing; a dry cask needs to be unloaded for testing which could determine transportability in 20-40 years. **(FS-14)**

NRC Response: The NRC interprets the comment to mean that heating and quenching for purposes of testing is inadequate because fuel will be ultimately loaded into a dry cask for disposal. Therefore, the cladding material should be tested in such a way to measure performance post-removal from the core, in dry cask storage. The NRC considers this comment outside the scope of this PRM because the comment addresses the performance of the fuel assembly in a storage case; whereas the focus of PRM-50-71 (and the 10 CFR 50.46c rulemaking) is on the performance of fuel in the reactor. In § 50.46, ECCS is judged to ensure coolable core geometry when fuel is loaded in the core. The NRC is forwarding the comment to the Office of Nuclear Material Safety and Safeguards which deals with discharged fuel concerns.

Comment: The phrases "within" approved cylindrical zirconium…and "based" alloy cladding…are not conservative. Such open-ended terms could be interpreted to include anything in the future. **(FS-16)**

NRC Response: The NRC disagrees with the comment. The wording in the current § 50.46 rule is very specific to zirconium alloy cladding. Other cladding materials, not composed (in whole or in part) of zirconium or not otherwise covered in other portions of the rule, would require an exemption to the rule. As previously noted, the proposed rule would essentially restructure the existing § 50.46. The proposed rule contains a paragraph which would establish generic performance-based requirements applicable to all LWR fuel designs, and specific performance-based requirements for fuel designs with uranium oxide or mixed uranium-oxide pellets within zirconium-oxide cladding material.

Comment: The proposed rule should note that if a fuel vendor's cladding has met the requirements for use on a generic basis, a process for the implementing utility to use that fuel under their existing operating license already exists. This would ensure that the cladding that has been approved for use by the vendor is appropriate for use in the utility's coolant system under all normal, abnormal, and accident conditions. **(PECO-1)**

NRC Response: The NRC agrees that the fuel vendor's cladding must be demonstrated to be acceptable for use by all licensees using that vendor's fuel. This may be accomplished through the licensee's submittal of an analysis of record that covers the applicable accidents and transients affected by the fuel cladding material.

Comment: Improvements to zirconium based cladding materials are important to support higher fuel burnup fuel management strategies. It is important to eliminate unnecessary administrative burden and make effective use of NRC, licensee and nuclear contractor resources. This PRM is consistent with the NRC movement towards performance based regulation. **(COMED-3)**

NRC Response: The NRC agrees with the comment, but notes that any new cladding material's behavior under LOCA conditions must be adequately characterized and analytical limits must be established which satisfy the general requirements of the proposed rule. The proposed rule would expand applicability to all fuel designs and cladding materials.

Comment: Updating the approved list of allowed fuel rod cladding materials as more products develop proven, in-reactor performance is a better alternative than provided in the petition. **(SCEG-10)**

NRC Response: The NRC disagrees with the comment. Because a licensee would need NRC approval to use a new cladding material, and because a vendor would need NRC approval of a topical report justifying the use of a new material, the NRC would have the opportunity to scrutinize the demonstrated performance of the new cladding material under normal and upset conditions, along with the supporting material's characterization, degradation mechanisms, mechanical testing database, and in-reactor performance.

Comment: The evaluations of cladding materials do not account for the realities of plant operation under normal conditions as well as the LOCA environment. The LOCA environment covers a range of scenarios depending on the time-temperature and thermal hydraulic path of the LOCAs. The procedure of heating in an inert atmosphere and then quickly quenching in cold water does not bound the severity of LOCA conditions. **(BL-1, BL-3)**

> **NRC Response**: The NRC disagrees with these comments. PQD testing involves mechanical tests of cladding previously exposed to high-temperature steam oxidation up to the maximum allowable cladding temperature, then quenched. The temperature profile was selected to bound LOCA scenarios.

Comment: The testing described in the petition does not require that the quenching tests of the cladding material be performed with cladding material that is preoxidized to depths that have occurred during reactor operation within technical specifications. This is inadequate because at least one LWR has operated with substantial oxide thickness on the zirconium fuel pins. **(BL-2)**

> **NRC Response**: The NRC disagrees with this comment. The effects of an existing cladding oxide layer on the rate of cladding oxidation and rate of embrittlement were investigated as part of the research and is documented in NUREG/CR-6967. In summary, the existence of an oxide layer itself has minimal impact. However, the presence of hydrogen within the cladding (associated with cladding corrosion) has a first order impact on the rate of embrittlement. This research finding is captured in the proposed rule.