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This section of the FEDERAL REGISTER contains notices to the public of the proposed issuance of rules and regulations. The purpose of these notices is to give interested persons an opportunity to participate in the rule making prior to the adoption of the final rules.

NUCLEAR REGULATORY COMMISSION

10 CFR Part 50

RIN 3150–AH42

[NRC–2008–0332]

Performance-Based Emergency Core Cooling System Acceptance Criteria

AGENCY: Nuclear Regulatory Commission.

ACTION: Advance notice of proposed rulemaking.

SUMMARY: This advance notice of proposed rulemaking (ANPR) presents a conceptual approach that the Nuclear Regulatory Commission (NRC) is considering in a rulemaking effort to revise the acceptance criteria for emergency core cooling systems (ECCSs) for light-water nuclear power reactors as currently required by NRC regulations that govern domestic licensing of production and utilization facilities. Revised ECCS acceptance criteria would reflect recent research findings that indicate the current criteria should be re-evaluated for all fuel cladding materials in all potential conditions. Further, the NRC is considering an approach that would expand the applicability of the rule to all current and future cladding materials, modify the reporting requirements, and address the issues raised in a petition for rulemaking (PRM) regarding crud and oxide deposits and hydrogen content in fuel cladding. With this ANPR, the NRC seeks comment on specific questions and issues for consideration related to this proposed conceptual approach to revising the ECCS acceptance criteria.

DATES: Submit comments by October 27, 2009. Comments received after this date will be considered if it is practical to do so, but the NRC is only able to ensure consideration of comments received on or before this date.

ADDRESSES: You may submit comments by any one of the following methods. Please include the following number RIN 3150–AH42 in the subject line of your comments. Comments on rulemakings submitted in writing or electronic form will be made available for public inspection. Because your comments will not be edited to remove any identifying or contact information, the NRC cautions you against including any information in your submissions that you do not want to be publicly disclosed.

We request that any party soliciting or aggregating comments received from other persons for submission to the NRC inform those persons that the NRC will not edit their comments to remove any identifying or contact information, and therefore they should not include any information in their comments that they do not want publicly disclosed. All commenters should ensure that sensitive or Safeguards Information is not contained in their responses or comments to this ANPR.

Federal e-Rulemaking Portal: Go to *http://www.regulations.gov* and search for documents filed under Docket ID NRC–2008–0332. Address questions about NRC dockets to Carol Gallagher (301) 492–3668; e-mail *Carol.Gallagher@nrc.gov*.

E-mail comments to: Rulemaking.Comments@nrc.gov. If you do not receive a reply e-mail confirming that we have received your comments, contact us directly at (301) 415–1677.

Mail comments to: Secretary, U.S. Nuclear Regulatory Commission, Washington, DC 20555–0001, ATTN: Rulemakings and Adjudications Staff.

Hand deliver comments to: 11555 Rockville Pike, Rockville, Maryland 20852, between 7:30 am and 4:15 pm during Federal workdays. (Telephone (301) 415–1677).

Fax comments to: Secretary, U.S. Nuclear Regulatory Commission at (301) 415–1101. You can access publicly available documents related to this document using the following methods:

NRC's Public Document Room (PDR): The public may examine and have copied for a fee, publicly available documents at the NRC's PDR, Public File Area Room O1–F21, One White Flint North, 11555 Rockville Pike, Rockville, Maryland. The PDR reproduction contractor will copy documents for a fee.

NRC's Agencywide Document Access and Management System (ADAMS): Publicly available documents created or received at the NRC are available electronically at the NRC's Electronic Reading Room at *http://www.nrc.gov/NRC/reading-rm/adams.html*. From this page, the public can gain entry into ADAMS, which provides text and image files of NRC's public documents. If you do not have access to ADAMS or if there are any problems in accessing the documents located in ADAMS, contact the NRC PDR Reference staff at (800) 397–4209, (301) 415–4737, or by e-mail to *PDR.resource@nrc.gov*.

FOR FURTHER INFORMATION CONTACT: Barry Miller, Mail Stop O–9E3, Office of Nuclear Reactor Regulation, U.S. Nuclear Regulatory Commission, Washington, DC 20555–0001; telephone (301) 415–4117, or e-mail *Barry.Miller@nrc.gov*.

SUPPLEMENTARY INFORMATION:

I. Background

In SECY–98–300, ''Options for Risk-Informed Revisions to 10 CFR part 50—'Domestic Licensing of Production and Utilization Facilities,' '' dated December 23, 1998 (ADAMS Accession number ML992870048), the NRC began to explore approaches to risk-informing its regulations for nuclear power reactors. One alternative (termed ''Option 3'') involved making risk-informed changes to the specific requirements in the body of Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50. As the NRC began to develop its approach to risk-informing these requirements, it sought stakeholder input in public meetings. Two of the regulations identified by industry as potentially benefitting from risk-informed changes were 10 CFR 50.44 and 10 CFR 50.46. Section 50.44 specifies the requirements for combustible gas control inside reactor containment structures and § 50.46 specifies the requirements for light-water power reactor emergency core cooling systems. For § 50.46, the potential was identified for making risk-informed changes to requirements for both ECCS cooling performance and ECCS analysis acceptance criteria in § 50.46(b).

Additionally, on March 14, 2000, as amended on April 12, 2000, the Nuclear Energy Institute (NEI) submitted a PRM requesting that the NRC amend its regulations in §§ 50.44 and 50.46 (PRM–50–71). The NEI petition noted that these two regulations apply to only two specific zirconium-based fuel cladding alloys (Zircaloy and ZIRLO™). NEI stated that reactor fuel vendors had subsequently developed new cladding materials other than Zircaloy and ZIRLO™ and that in order for licensees to use these new materials under the regulations, licensees had to request NRC approval of exemptions from §§ 50.44 and 50.46. On September 16, 2003, (68 FR 54123), the NRC amended § 50.44 to include new, risk-informed requirements for combustible gas control. The regulation was also modified to be applicable to all boiling or pressurized water reactors regardless of the type of fuel cladding material utilized.

On March 3, 2003, in response to SECY–02–0057, ''Update to SECY–01–0133, 'Fourth Status Report on Study of Risk-Informed Changes to the Technical Requirements of 10 CFR Part 50 (Option 3) and Recommendations on Risk-Informed Changes to 10 CFR 50.46 (ECCS Acceptance Criteria)' '', the Commission issued a staff requirements memorandum (SRM) (ADAMS Accession number ML030910476) directing the NRC staff to move forward to risk-inform its regulations in a number of specific areas. Among other things, this SRM directed the NRC staff to modify the ECCS acceptance criteria to provide for a more performance-based approach to meeting the ECCS requirements in § 50.46.

Separately from the Commission's efforts to modify its regulations to provide a more risk-informed, performance-based regulatory approach, the NRC had also undertaken a fuel cladding research program intended to investigate the behavior of high exposure fuel cladding under accident conditions. This research program included an extensive loss-of-coolant accident (LOCA) research and testing program at Argonne National Laboratory (ANL), as well as jointly funded programs at the Kurchatov Institute and the Halden Reactor project, to develop the body of technical information needed to support the new regulations.

The effects of both alloy composition and fuel burnup (the extent to which fuel is used in a reactor) on cladding embrittlement (*i.e.,* loss of ductility) under accident conditions were studied in this research program. The research program identified new cladding embrittlement mechanisms and expanded the NRC's knowledge of previously identified mechanisms. The research results revealed that alloy composition has a minor effect on embrittlement, but the cladding corrosion which occurs as fuel burnup increases has a substantial effect on embrittlement. One of the major findings of NRC's research program was that hydrogen, which is absorbed in the cladding during the burnup-related corrosion process under normal operation, has a significant influence on the embrittlement during a hypothetical accident. Increased hydrogen content increases both the solubility of oxygen in zirconium and the rate at which it is absorbed, thus increasing the amount of oxygen in the metal during high temperature oxidation in LOCA conditions. Oxygen is what ultimately causes embrittlement in zirconium, but hydrogen content is a good indicator of burnup embrittlement effects because of its ability to allow this increased oxygen absorption. Because of hydrogen's effect, the embrittlement thresholds can be correlated with the pre-accident hydrogen concentration. Further, the NRC's research program found that oxygen from the oxide fuel pellets enters the cladding from the inner surface if a bonding layer exists between the fuel pellet and the cladding, in addition to the oxygen that enters from the oxide layer on the outside of the cladding. Moreover, under conditions that might occur during a small-break LOCA [such as an extended time-at-temperature below 1000 degrees Centigrade (°C) (1832 degrees Fahrenheit (°F))], the accumulating oxide on the surface of the cladding can break up; this can allow large amounts of hydrogen to diffuse into the cladding, thus exacerbating the embrittlement process.

The research results also confirmed an older finding that if cladding rupture occurs during a LOCA, large amounts of hydrogen produced from the steam-cladding reaction can enter the cladding inside surface near the rupture location. These research findings have been summarized in Research Information Letter (RIL) 0801, ''Technical Basis for Revision of Embrittlement Criteria in 10 CFR 50.46,'' (ADAMS Accession number ML081350225) and the detailed experimental results from the program at ANL are contained in NUREG/CR–6967, ''Cladding Embrittlement during Postulated Loss-of-Coolant Accidents'' (ADAMS Accession number ML082130389).

In response to the research findings identified in RIL 0801, the NRC completed a preliminary safety assessment of currently operating reactors (ADAMS Accession number 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, any changes to the ECCS acceptance criteria to account for the new findings can reasonably be addressed through rulemaking.

After the NRC publicly released the technical basis information in RIL 0801 on May 30, 2008, and NUREG/CR–6967, on July 31, 2008, it published a **Federal Register** (FR) document on July 31, 2008, (73 FR 44778), requesting that public stakeholders comment on the adequacy of the technical basis and identify issues that may arise with respect to experimental data development, regulatory costs, or impacts of potential new requirements. The comments received in response to this document can be found at *http://www.regulations.gov* by searching on docket ID NRC–2008–0332. On September 24, 2008, the NRC held a public workshop to discuss stakeholder comments on the adequacy of the technical basis and to give the public and industry another opportunity to provide further comment and input. The workshop included presentations and open discussion between representatives of the NRC, international regulatory and research agencies, domestic and international commercial power firms, fuel vendors, and the general public. The meeting summary, including a list of attendees and presentations, is available at ADAMS Accession number ML083010496.

Since 2002, the NRC has met with the Advisory Committee on Reactor Safeguards (ACRS) multiple times to discuss the progress of the LOCA research program and rulemaking proposals. Provided in the table below are the dates and ADAMS Accession numbers of the relevant ACRS meetings and associated correspondence.

Date	Meeting/letter	ADAMS accession number
October 9, 2002	Subcommittee Meeting	ML023030246 *
October 10, 2002	Full Committee Meeting	ML022980190 *
October 17, 2002	Letter from ACRS to NRC staff	ML022960640
December 9, 2002	Response letter from NRC staff to ACRS	ML023260357
September 29, 2003	Subcommittee Meeting	ML032940296 *

Date	Meeting/letter	ADAMS accession number
July 27, 2005	Subcommittee Meeting	ML052230093 *
September 8, 2005	Full Committee Meeting	ML052710235 *
January 19, 2007	Subcommittee Meeting	ML070390301 *
February 2, 2007	Full Committee Meeting	ML070430485 *
May 23, 2007	Letter from ACRS to NRC staff	ML071430639
July 11, 2007	Response letter from NRC staff to ACRS	ML071640115
December 2, 2008	Subcommittee Meeting	ML083520501 * & ML083530449
December 4, 2008	Full Committee Meeting	ML083540616 *
December 18, 2008	Letter from ACRS to NRC staff	ML083460310
January 23, 2009	Response letter from NRC staff to ACRS	ML0836640532

* ADAMS file is a transcript of the ACRS meeting.

On March 15, 2007, Mark Leyse submitted to the NRC a PRM (ADAMS Accession number ML070871368). In the petition, which was docketed as PRM 50–84, the petitioner requested that all holders of operating licenses for nuclear power plants be required to operate such plants at operating conditions (*e.g.,* levels of power production, and light-water coolant chemistries) necessary to effectively limit the thickness of crud [1] and/or oxide layers on fuel rod cladding surfaces. The petitioner requested the NRC to conduct rulemaking in the following three specific areas:

(1) Establish regulations that require licensees to operate light-water power reactors under conditions that are effective in limiting the thickness of crud and/or oxide layers on zirconium-clad fuel in order to ensure compliance with § 50.46(b) ECCS acceptance criteria;

(2) Amend Appendix K to 10 CFR part 50 to explicitly require that the steady-state temperature distribution and stored energy in the reactor fuel at the onset of a postulated LOCA be calculated by factoring in the role that the thermal resistance of crud deposits and/or oxide layers 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); and

(3) Amend § 50.46 to specify a maximum allowable percentage of hydrogen content in [fuel rod] cladding.

[1] Crud is a foreign substance which may be deposited on the surface of fuel cladding which can impede the transfer of heat. Crud most frequently refers to deposits of iron or nickel metallic particles eroded from pipe and valve surfaces. These particles of stable isotopes may become ''activated'' when they are irradiated in the reactor and transform into radioactive isotopes such as cobalt-60. The NRC makes a distinction between crud and pure zirconium oxidation layers. Although both materials contain metal oxides, crud does not originate at the fuel rod, while zirconium oxide forms on fuel cladding when the cladding material reacts with oxygen.

On May 23, 2007, (72 FR 28902), the NRC published a notice of receipt for this petition in the FR and requested public comment on the petition. The public comment period ended on August 6, 2007. After evaluating the public comments, the NRC resolved the Leyse petition by deciding that each of the petitioner's issues should be considered in the rulemaking process. The NRC's determination was published in the FR on November 25, 2008, (73 FR 71564).

Because the issues raised in PRM–50–84 pertain to ECCS analysis and acceptance criteria, the need for rulemaking to address the petitioner's technical concerns will be addressed in this rulemaking. Technical details associated with the NRC's evaluation of the rulemaking requests in PRM–50–84 are discussed in Section III.4 of this document.

II. Rulemaking Objectives

The scope of the rulemaking contemplated by this ANPR includes four separate rulemaking objectives:

Objective 1: Expand the applicability of § 50.46 to include any light-water reactor fuel cladding material:

In this rulemaking, the NRC is considering expansion of the rule's applicability (which currently addresses only Zircaloy and ZIRLO™ cladding) to include any light-water reactor fuel cladding material. As used in this ANPR, the term ''fuel cladding'' (or simply ''cladding'') refers only to the cylindrical material that surrounds and contains the nuclear fuel, not a fuel/cladding system. The rulemaking may clarify the general applicability of § 50.46 to require that all light-water nuclear power reactors must be provided with an ECCS designed so that after a postulated LOCA, a coolable core geometry would be maintained, excessive combustible gases would not be generated, and long-term cooling would be assured. The applicability expansion would also encompass the request in PRM–50–71, filed by NEI (see 65 FR 34599; May 31, 2000, and 73 FR 6600; November 6, 2008), to establish requirements that apply to all zirconium-based cladding alloys, including current and anticipated alloys. The NRC's high-burnup fuel research program investigated cladding embrittlement in a number of different zirconium-based cladding alloys and concluded that the results were applicable equally to all of the zirconium-based alloys. Therefore, new zirconium-specific criteria can be formulated in a performance-based manner that would satisfy the request in PRM–50–71. Because this applicability expansion may also aim to encompass any potential new cladding materials developed in the future that are not zirconium-based, the NRC notes that such materials would still need an extensive technical foundation to receive NRC approval. However, this applicability expansion would eliminate the need for licensees to request, and the NRC to review and approve, exemptions from § 50.46 for these potential new non-zirconium cladding materials.

Objective 2: Establish performance-based requirements and acceptance criteria specific to zirconium-based cladding materials that reflect recent research findings:

The second objective of this rulemaking is to enhance the performance-based features of § 50.46 by replacing the current § 50.46(b) prescriptive analytical limits with fuel cladding performance requirements and acceptance criteria. These performance requirements, based upon the recent findings from the NRC's high burnup research program, would ensure that an adequate level of cladding ductility is maintained throughout a postulated LOCA.

Objective 3: Revise the LOCA reporting requirements:

The third objective of this rulemaking is to amend § 50.46(a)(3)(i) to emphasize the importance of reporting reduction in margins to the acceptance criteria and the periodic reporting of susceptibility to breakaway oxidation.

Objective 4: Address the issues raised in PRM–50–84, which relate to crud deposits and hydrogen content in fuel cladding:

The fourth objective of this rulemaking is to amend § 50.46 as necessary to address the technical issues on which the PRM–50–84 petitioner's three requests for rulemaking are based. The need for and extent of any changes that may be needed to address these issues will be determined during this rulemaking.

III. Specific Proposals

The NRC presents the following conceptual approach to revising 10 CFR 50.46 under the outlined objectives:

Objective 1: Expand the applicability of § 50.46 to include any light-water reactor fuel cladding material:

This first conceptual approach involves the applicability of the rule as defined in § 50.46(a)(1)(i). Currently, this provision is limited to fuel rods clad in Zircaloy or ZIRLO™. The recent LOCA research program conducted testing on a wide range of zirconium-based alloys such that research findings and future testing requirements are believed to be applicable to all zirconium-based alloys. Therefore, the NRC intends to expand the applicability of the rule to all zirconium-based alloys. This would allow the introduction of future, advanced zirconium-based alloys without the need for exemption requests. However, NRC approval would still be required.

In addition, the NRC is considering further expansion of the rule's applicability to include all light-water reactors (LWRs) without regard to the type of fuel cladding material utilized in the design. Currently, § 50.46 states that the ECCS must be designed so that its calculated cooling performance following postulated LOCAs conforms to the five criteria set forth in § 50.46(b). To accomplish such a change, the NRC is considering an approach where the proposed revision would specify that all fuel cladding material used in LWRs, without regard to its composition, must satisfy the three general conditions which currently exist as the criteria specified in § 50.46(b)(3) Maximum hydrogen generation, § 50.46(b)(4) Coolable geometry, and § 50.46(b)(5) Long-term cooling. The § 50.46(b)(3) criterion would be modified to limit generation of any combustible gas, rather than just hydrogen, with recognition that different cladding materials could potentially react to produce different combustible gases. Because the NRC's recent research findings are only applicable to LWRs with zirconium-based cladding alloys, detailed ECCS acceptance criteria for different cladding materials could not now be specified in the regulations. Therefore, the NRC is considering a cladding-specific regulatory approach that would require applicants with non-zirconium cladding materials to propose specific detailed criteria to demonstrate how coolable core geometry, long-term cooling, and minimal generation of combustible gases would be ensured. In order to develop such cladding-specific criteria, applicants would need to fully develop and understand all of the material's degradation mechanisms, chemical and physical properties, and any other characteristics that may affect its behavior in the core during normal operation and under LOCA conditions. The NRC would review the applicant's proposed criteria and issue its approval only if the criteria ensure that the three general conditions are met, that the cladding-specific criteria can be demonstrated to be met during all credible LOCA scenarios, and that they are sufficient to ensure adequate protection of public health and safety. Section IV of this document requests comment on this conceptual approach to expanding the rule's applicability.

For LWRs using zirconium-based alloys, cladding-specific criteria can and will be specified in the regulations based on the results of the NRC's LOCA research program. These criteria will ensure adequate cladding ductility is maintained via specified performance requirements. A general discussion on the nature of these criteria is provided below under Objective 2.

Objective 2: Establish performance-based requirements and acceptance criteria specific to zirconium-based cladding materials that reflect recent research findings:

Cladding Ductility

In the current rule, the preservation of cladding ductility, via compliance with regulatory criteria on peak cladding temperature (§ 50.46(b)(1)) and local cladding oxidation (§ 50.46(b)(2)), ensures that the core remains amenable to cooling. The recent LOCA research program identified new cladding embrittlement mechanisms which demonstrated that the current combination of peak cladding temperature (2200 °F (1204 °C)) and local cladding oxidation (17 percent equivalent cladding reacted (ECR)) criteria do not always ensure post quench ductility (PQD). It is important to recognize that the loss of cladding ductility is the result of oxygen diffusion into the base metal and not directly related to the growth of a zirconium dioxide layer on the cladding outside diameter. In the current provision, the peak local oxidation limit is used as a surrogate to limit time at elevated temperature and associated oxygen diffusion. This surrogate approach is possible because both oxidation and diffusion share a strong temperature dependence. In the recent LOCA research program, the Cathcart-Pawel (CP) weight gain correlation was used to quantify the time at elevated temperature at which ductility was lost (nil ductility). For this reason, the proposed amendment would include a requirement that local cladding oxidation (which is being used as a surrogate for limiting time-at-temperature) be calculated using the same Cathcart-Pawel correlation (see Regulatory Guide 1.157 regarding use of the Cathcart-Pawel oxidation correlation rather than the Baker-Just correlation cited in 10 CFR part 50, Appendix K, Part I.A.5).

To enhance the performance-based aspects of § 50.46 (and achieve an objective of this rulemaking), the limits on peak cladding temperature and local oxidation would be replaced with specific cladding performance requirements and acceptance criteria which ensure that an adequate level of cladding ductility is maintained throughout the postulated LOCA. For example, the rule may specify that retention of cladding ductility is defined 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 millimeters per second (mm/sec). Section IV of this document requests comment on alternative ways to define an acceptable measure of ductility. This acceptance criterion would be used to define analytical limits for peak cladding temperature and local oxidation based on cladding performance during tests in which cladding specimens are exposed to double-sided steam oxidation up to a specified peak oxidation temperature and CP–ECR. Analytical limits would be calculated as a function of initial cladding hydrogen content (weight parts per million (wppm) in metal). The NRC intends to issue a regulatory guide detailing an acceptable experimental test methodology for defining analytical limits in accordance with these performance requirements. Included in this test methodology would be guidance for treating ring-compression test results which fail in such a way that permanent strain cannot be measured. The guidance would provide a relationship of permanent strain to offset-displacement.

This ANPR also provides two possible approaches for determining the acceptability of current and future cladding alloys in accordance with the proposed performance requirements. Two approaches are described as follows, however the NRC recognizes there may be other alternatives.

Approach A—Analytical Limits Defined Within Regulatory Guidance:

The focal point of this approach would be a future regulatory guidance document which defines an acceptable, generically-applicable set of analytical limits for peak cladding temperature and maximum allowable time-at-temperature (expressed as calculated local oxidation, CP–ECR) as a function of pre-transient hydrogen content in the cladding metal, excluding hydrogen in the cladding oxide layer. These acceptable analytical limits would be based on the results of NRC's LOCA research program. Appendix A of this document outlines the conceptual path for approving both current and future cladding alloys using this approach.

Approach B—Cladding-Specific Analytical Limits Defined by an Applicant:

The second approach involves establishing cladding-specific and/or temperature-specific analytical limits for peak cladding temperature and maximum allowable time-at-temperature (expressed as calculated local oxidation, CP–ECR) as a function of pre-transient hydrogen content in the cladding metal, excluding hydrogen in the cladding oxide layer. This approach would provide optimum flexibility for defining more specific analytical limits to gain margin to the ECCS performance criteria. However, unlike citing analytical limits within a regulatory guide, this approach places the burden of proof on the applicant to validate their analytical limits and address experimental variability and repeatability. As a result, this approach would necessitate a larger number of PQD tests (relative to confirming the applicability of the regulatory guide). Analytical limits, along with the experimental procedures, protocols, and specimen test results used in their development, would be subject to NRC review and approval. Appendix B of this document includes further discussion to illustrate the possible implementation of this approach.

Cladding embrittlement is highly sensitive to both hydrogen content and peak oxidation temperature, and this relationship is applicable to both approaches. The discussion in the Appendices to this document describes an approach that would demonstrate compliance with the proposed change and illustrate this relationship.

Implementing any hydrogen based analytical limits, similar to the descriptions contained in the Appendices, requires an accurate, alloy-specific hydrogen uptake model. Section IV of this document seeks comment on the development of these models and how best to deal with the axial, radial, and circumferential variability in hydrogen concentration.

Two-Sided Oxidation

Prompted by research which found that oxygen from the inside diameter fuel bonding layer present in high burnup fuel rods may diffuse into the base metal of the cladding, the NRC is proposing a new analytical requirement to specifically account for the potential diffusion of oxygen from the cladding inside diameter. Because the formation of a fuel bonding layer may depend on fuel rod design and power history, licensees would be required to develop and justify a burnup threshold above which this phenomenon would be specifically accounted for within local cladding oxidation calculations.

Breakaway Oxidation

The NRC may also propose new requirements addressing breakaway oxidation. The recent LOCA research program discovered that the protective cladding oxide layer will undergo a phase transformation, become unstable, and allow for the uptake of hydrogen into the base metal. The timing of this transformation is sensitive to many parameters including the cladding manufacturing process. Licensees would be responsible for ensuring that the timing of the oxide phase transformation is measured for each cladding alloy utilized in their core to determine susceptibility to early breakaway oxidation. The proposed rule would specify the required testing method, along with an acceptable measure of breakaway oxidation behavior. The NRC intends to issue a regulatory guide detailing an acceptable experimental methodology for defining new criteria under these requirements. For example, the proposed rule may specify that the minimum measured time until the onset of breakaway oxidation, defined as when hydrogen uptake reaches 200 wppm anywhere on a cladding segment subjected to high temperature steam oxidation ranging from 1200 °F to 1875 °F (649 °C to 1024 °C), shall remain greater than the calculated duration that cladding surface temperature anywhere on the fuel rod remains above 1200 °F (649 °C).

The measured timing of the oxide phase transformation for each cladding alloy, along with the experimental procedures and protocols used in their development, would be subject to NRC review and approval. Section IV of this document seeks public comment on a draft experimental methodology for conducting breakaway oxidation testing with zirconium-based cladding alloys.

Application of the proposed breakaway oxidation criterion would involve new analytical requirements, including an additional break spectrum analysis to identify the limiting combination of inputs that maximize the time above elevated temperatures which are susceptible to breakaway oxidation for the given cladding alloy (*e.g.,* 1200 °F (649 °C)). Each licensee would be required to demonstrate that this calculated duration remained below the measured minimum time to breakaway oxidation. As an alternative, the NRC is considering tying breakaway oxidation to the rule's applicability statement. For example, the proposed revision would only be applicable to zirconium-based alloys which do not experience the breakaway phenomena within a specified time period. This approach would eliminate the need for each licensee to perform and maintain a current updated final safety analysis report (UFSAR) break spectrum analysis for breakaway oxidation. To set the specified time period within the proposed rule's applicability statement, the NRC is seeking 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. If successful, this alternative approach would include a simpler pass/fail breakaway testing requirement up to this specified time period (as opposed to searching for and quantifying the limiting time to breakaway). Section IV of this document seeks to obtain this input.

Objective 3: Revise the LOCA reporting requirements.

Redefining a Significant Change or Error:

The reporting requirement in 10 CFR 50.46(a)(3)(i) currently defines a significant change or error as one that results in a calculated peak cladding temperature (PCT) different by more than 50 °F (28 °C) from the temperature calculated for the limiting transient using the last acceptable model, or is a cumulation of changes and errors such that the sum of the absolute magnitudes of the respective temperature changes is greater than 50 °F (28 °C).

The NRC is considering revising the reporting requirements by redefining what constitutes a significant change or error in such a manner as to make the reporting requirements dependent upon the margin between the acceptance criteria limits and the calculated values of the respective parameters (*i.e.,* PCT or CP–ECR). The redefinition would aim to capture the importance of being close to the limits by making reporting of a change dependent upon the margin to the acceptance criteria. The NRC believes this redefinition should also expand the current reporting scope to include CP–ECR, in addition to PCT, as a parameter required for reporting. The timeliness requirements for reporting would remain the same (*i.e.,* 30 days for a significant change or error). The following definitions exemplify a specific approach the NRC is considering:

If the calculated parameter (PCT or CP–ECR) has margin greater than 5 percent of its acceptance criterion limit, then a significant change or error is one that results in:

(i) A PCT change of 100 °F (56 °C) or greater,

(ii) A CP–ECR change of 2 percent or greater, or

(iii) An accumulation of changes and errors such that the sum of the absolute magnitudes of the changes and errors is greater than 100 °F (56 °C) or 2 percent, respectively.

If the calculated parameter (PCT or CP–ECR) is within 5 percent of its acceptance criterion limit, then a significant change or error is one that results in a calculated 10 percent or greater reduction in the remaining margin.

The following table gives an example for how the PCT criterion reporting would be ''triggered'' for a plant with a PCT limit of 2200 °F.

Calculated PCT	Reporting trigger
< 2090 (*i.e.,* not within 5 percent of 2200 °F limit).	Any change ≥ 100 °F.
2090–2099 °F	Any change ≥ 11 °F.
2100–2109 °F	Any change ≥ 10 °F.
2110–2119 °F	Any change ≥ 9 °F.
2120–2129 °F	Any change ≥ 8 °F.
2130–2139 °F	Any change ≥ 7 °F.
2140–2149 °F	Any change ≥ 6 °F.
2150–2159 °F	Any change ≥ 5 °F.
2160–2169 °F	Any change ≥ 4 °F.
2170–2179 °F	Any change ≥ 3 °F.
2180–2189 °F	Any change ≥ 2 °F.
2190–2199 °F	Any change ≥ 1 °F.

The NRC recognizes that there are other possible approaches for implementing the concept that the reporting obligation depends upon the margin to the relevant acceptance criteria. Section IV of this document seeks specific comment on this approach to modifying the reporting requirements.

Breakaway Oxidation Susceptibility Reporting

The NRC is also considering reporting requirements related to breakaway oxidation. Different zirconium-based alloys have varying susceptibility to breakaway oxidation that is dependent on factors such as alloy content, manufacturing process, and surface preparation, among others. The NRC is concerned that during the life-cycle of an alloy used by a fuel vendor, both intentional and unintentional changes may be made in the aforementioned conditions. The effect of the changes can only be determined by testing samples throughout the life-cycle of an alloy of the current cladding material for breakaway oxidation potential. The NRC plans to propose to include periodic testing of cladding samples as part of the annual licensee report pertaining to the LOCA licensing basis. The new requirement would be consistent with the following concept: licensees would report to the NRC at least annually as specified in §§ 50.4 or 52.3, as applicable, results of testing of each type of zirconium-based cladding alloy employed in their reactor core for susceptibility to breakaway oxidation. If a cladding alloy is found to have greater susceptibility to breakaway oxidation than would be acceptable for the corresponding time-at-temperature of the ECCS performance analysis, the affected licensee would be required to propose immediate steps to reduce the impact of breakaway oxidation on their ECCS performance analysis. Section IV of this document seeks specific comment on this approach to modifying the reporting requirements.

Objective 4: Address the issues raised in PRM–50–84, which relate to crud deposits and hydrogen content in fuel cladding:

In this ANPR, the NRC addresses the three requests for rulemaking in PRM–50–84:

(1) Establish regulations that require licensees to operate light-water power reactors under conditions that are effective in limiting the thickness of crud and/or oxide layers on zirconium-clad fuel in order to ensure compliance with § 50.46(b) ECCS acceptance criteria;

(2) Amend Appendix K to 10 CFR part 50 to explicitly require that the steady-state temperature distribution and stored energy in the reactor fuel at the onset of a postulated LOCA be calculated by factoring in the role that the thermal resistance of crud deposits and/or oxide layers 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); and

(3) Amend § 50.46 to specify a maximum allowable percentage of hydrogen content in [fuel rod] cladding.

PRM–50–84 Rulemaking Requests 1 and 2

Because the petitioner's first two requests for rulemaking are technically related, they are addressed together in the following discussion. When evaluating PRM–50–84, the NRC reviewed the technical information provided by the petitioner and by all public commenters. The NRC's detailed analysis of all public comments was published in the FR on November 25, 2008 (73 FR 71564). A summary of key comments that influenced the NRC's conclusions follows.

The NEI opposed granting PRM–50–84 because the petition relies heavily on atypical operating experiences at four plants: River Bend (1998–1999 and 2001–2003), Three Mile Island Unit 1 (1995), Palo Verde Unit 2 (1997), and Seabrook (1997), where thick crud layers developed during normal operation. NEI stated that the incidents cited by the petitioner were isolated operational events and would not have been prevented by imposing specific regulatory limits on crud thickness. NEI noted that the industry is actively pursuing root cause evaluations and has developed corrective actions to mitigate further cases of excessive crud formation.

NEI also stated that reactor licensees use approved fuel performance models to determine fuel rod conditions at the start of a LOCA. NEI stated that the impact of crud and oxidation on fuel temperatures and pressures may be determined explicitly or implicitly in the system of models used. NEI referenced the NRC review guidance in the Standard Review Plan (SRP) (NUREG–0800) noting that SRP Section 4.2 states that the impact of corrosion on thermal and mechanical performance should be considered in the fuel design analysis, when comparing to the design stress and strain limits. NEI and industry commenters in general opposed issuing new regulations related to crud, stating that the existing regulations and voluntary guidance regarding crud are sufficient.

The NRC agrees with NEI that new requirements imposing specific regulatory limits on crud thickness would not necessarily have prevented the occurrences of heavy crud deposits that were the unexpected consequences of the operational events cited in PRM–50–84. Nevertheless, formation of cladding crud and oxide layers is an expected condition at nuclear power plants. Although the thickness of these layers is usually limited, the amount of accumulated crud and oxidation varies from plant to plant and from one fuel cycle to another. Intended or inadvertent changes to plant operational practices may result in unanticipated levels of crud deposition. The NRC agrees with the petitioner that crud and/or oxide layers may directly increase the stored energy in reactor fuel by increasing the thermal resistance of cladding-to-coolant heat transfer, and may also indirectly increase the stored energy through an increase in the fuel rod internal pressure.

As previously discussed, NEI commented that reactor licensees use approved fuel performance models to determine fuel rod conditions at the start of a LOCA and that the impact of crud and oxidation on fuel temperatures and pressures may be determined explicitly or implicitly by the system of models used. The NRC believes that to accurately model fuel performance during normal and postulated accident conditions, it is essential that fuel performance and LOCA evaluation models include the thermal effects of both crud and oxidation whenever their accumulation changes the calculated results. Recently, power reactor licensees have been submitting an increased number of license amendment applications requesting significant increases in licensed power levels. In some cases, these increases have reduced the margin between calculated ECCS performance and current ECCS acceptance criteria. This trend further supports the need to ensure that the effects of both crud and oxidation are properly accounted for in ECCS analyses. The technical concerns related to the thermal effects of oxidation and crud raised by the petitioner's rulemaking requests are addressed separately below.

Oxidation. The accumulation of cladding oxidation and its associated effects on fuel cladding acceptance criteria are being addressed by the ongoing work to revise the ECCS acceptance criteria. Thus, the concerns related to oxidation raised by the petitioner's rulemaking requests are encompassed by Objective 2 of this section.

Crud. 10 CFR 50.46 requires the licensee of a facility to perform LOCA accident analyses to demonstrate that a nuclear reactor has an ECCS that is designed so its calculated performance meets the acceptance criteria in § 50.46(b) on peak clad temperature (2200 °F) and maximum local oxidation (17 percent). Licensees must evaluate a plant's ECCS by calculating its performance with an acceptable evaluation model. An acceptable model is one that either complies with the required and acceptable features in Appendix K to Part 50—ECCS Evaluation Models; or, for best-estimate models, complies with the § 50.46(a)(1)(i) requirement that there is a high level of probability that the calculated cooling performance will not exceed the acceptance criteria in § 50.46(b). The NRC reviews and approves all licensee evaluation models to determine if they are acceptable.

For best-estimate evaluation models, § 50.46(a)(1)(i) requires that ''The evaluation model must include sufficient supporting justification to show that the analytical technique realistically describes the behavior of the reactor coolant system during a loss-of-coolant accident.'' For Appendix K models, section I.B. of Appendix K to Part 50 states, ''The calculations of fuel and cladding temperatures as a function on time shall use values for gap conductance and other thermal parameters as functions of temperature and other applicable time-dependent variables.'' Crud accumulation and its effects are not explicitly identified as required parameters to be included in best-estimate or Appendix K to Part 50 models.

However, based on these requirements, the NRC has prepared regulatory review guidance that addresses the accumulation of crud and oxidation deposits on fuel cladding surfaces. This guidance is in the format of review criteria in NUREG–0800, ''Standard Review Plan (SRP)'' which are used by the NRC staff to review licensees' evaluation models. SRP Section 4.2, ''Fuel System Design,'' Section 4.3, ''Nuclear Design,'' and Section 4.4, ''Thermal and Hydraulic Design'' all contain specific criteria related to the accumulation of crud and oxidation on fuel cladding surfaces. For example, on page 4.2–6 of SRP Section 4.2.2, fuel system damage acceptance criterion iv. states:

> iv. Oxidation, hydriding, and the buildup of corrosion products (crud) should be limited, with a limit specified for each fuel system component. These limits should be established based on mechanical testing to demonstrate that each component maintains acceptable strength and ductility. The safety analysis report should discuss allowable oxidation, hydriding, and crud levels and demonstrate their acceptability. These levels should be presumed to exist in items (i) and (ii) above. The effect of crud on thermal hydraulic considerations and neutronic (AOA)[2] considerations are reviewed as described in SRP Sections 4.3 and 4.4.

Page 4.2–15 of SRP Section 4.2 also states that the calculational models used to determine fuel temperature and stored energy should include phenomenological models addressing ''Thermal conductivity of the fuel, cladding, cladding crud and oxidation layers'' and ''Cladding oxide and crud layer thickness.'' Review criteria in SRP Section 4.4 specifically note that the thickness of oxidation layers and crud deposits must be accounted for in critical heat flux calculations and when determining the pressure drop throughout the reactor coolant system.

The NRC review guidance in the SRP supports interpreting § 50.46(a) and Appendix K to Part 50 to include crud as a required parameter in these analyses. However, because crud is not explicitly identified in the regulations and the regulatory guidance in the SRP is not an enforceable requirement, there is ambiguity in the current requirements. The NRC is considering amending its regulations to explicitly identify crud as one of the parameters that must be addressed in ECCS analysis models. This change would eliminate any ambiguity between the current rule language and the current SRP review guidance. Licensee evaluation models could be formulated to calculate the accumulation of crud or assume an expected maximum thickness. The resulting effects on fuel temperatures would be determined based on the predicted or assumed thickness of deposits.

The NRC also notes that licensees are required to operate their facilities within the boundaries of the calculated ECCS performance. During or immediately after plant operation, if actual crud layers on reactor fuel are implicitly determined or visually observed after shutdown to be greater than the levels predicted by or assumed in the evaluation model, licensees would be required to determine the effects of the increased crud on the calculated ECCS results. In many cases, engineering judgment or simple calculations could be used to evaluate the effects of increased crud levels; therefore, detailed LOCA reanalysis may not be required. In other cases, new analyses would be performed to determine the effect the new crud

[2] AOA means Axial Offset Anomaly.

conditions have on the final calculated results.

The NRC would consider the deposition of a previously unanalyzed amount of crud to be the same as making a change to or finding an error in an approved evaluation model or in the application of such a model. In these cases, § 50.46(a)(3)(i) requires licensees to determine if the change or error is significant. For significant changes, § 50.46(a)(3)(ii) requires licensees to provide, within 30 days, a report to the NRC including a schedule for providing a reanalysis or taking other action as may be needed to show compliance with the § 50.46 requirements. In situations when the § 50.46(b) acceptance criteria are not exceeded, the licensee could either change the ECCS analysis of record to conform to the new crud level or make changes to plant design or operation (*e.g.,* adjust water coolant chemistry) to reduce crud deposits to the level assumed in the original analysis. Situations where a model change or error correction results in calculated ECCS performance that does not conform to the acceptance criteria in § 50.46(b) would be reportable events as described in §§ 50.55(e), 50.72, and 50.73. In these situations, the licensee would be required under § 50.46(a)(3)(ii) to propose immediate steps to demonstrate compliance or bring the plant design or operation into compliance with § 50.46 requirements.

In summary, to address the technical concerns related to crud in the PRM–50–84 petitioner's requests for rulemaking, the NRC is considering amending § 50.46(a) to specifically identify crud as a parameter to be considered in best-estimate and Appendix K to Part 50 ECCS evaluation models. Compliance with this requirement during plant operation would be determined by the process outlined in the scenarios above.

Under this approach, the NRC would propose new rule language defining crud as a foreign substance (other than zirconium oxide) which may be deposited on the surface of fuel cladding and which impedes the transfer of heat due to thermal resistance and/or flow area reduction. A requirement would be added stating that ECCS evaluation models must consider the effects of crud deposition on fuel cladding at the highest level of buildup expected during a fuel cycle. In addition, to ensure that plant-specific crud levels are bounded by the levels analyzed in the ECCS model, the NRC is considering adding a requirement that licensees inspect one or more fuel assemblies every fuel cycle to determine the actual thickness of crud on the fuel. Section IV of this document requests comment on the potential addition of such a requirement.

PRM–50–84 Rulemaking Request 3

The petitioner's third request for rulemaking—that the NRC amend § 50.46 to specify a maximum allowable percentage of hydrogen content in cladding—pertains to the effects on fuel cladding embrittlement caused by hydrogen in the cladding. The cladding embrittlement issue will be technically resolved by revising the ECCS analysis embrittlement acceptance criteria under rulemaking Objective 2. These new acceptance criteria will address the embrittlement effects of cladding hydrogen content and other pertinent variables.

IV. Issues for Consideration

Based on the specific proposals and discussion above, the NRC requests comment on the following questions and issues. In submitting comments, the NRC asks that each comment be referenced to its corresponding question or issue number, as indicated below.

Applicability Considerations

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

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

New Embrittlement Criteria Considerations

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 NSSS/ECCS design combinations. This information may be used to set a specified minimum time to breakaway in the proposed rule's applicability statement.

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

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 this document.

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 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.

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 the 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.

Testing Considerations

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

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 number 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?

Revised Reporting Requirements Considerations

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

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

Crud Analysis Considerations

10. The NRC requests comment on the proposed regulatory approach in which crud is required to be considered in ECCS evaluation models. If actual crud levels should exceed the levels considered in the evaluation model, the situation would be considered equivalent to discovering an error in the ECCS model. The licensee would then be subject to the reporting and corrective 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.

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

Cost Considerations

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–2008–0332–0008.1 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.

Available Supporting Documents

The following documents provide additional background and supporting information regarding this rulemaking activity and corresponding technical basis. The documents can be found in the NRC's Agencywide Document Access and Management System (ADAMS). Instructions for accessing ADAMS were provided under the **ADDRESSES** section of this document.

Date	Document	ADAMS accession number
July 31, 2008	NUREG/CR–6967, "Cladding Embrittlement During Postulated Loss-of-Coolant Accidents".	ML082130389.
May 30, 2008	Research Information Letter (RIL) 0801, "Technical Basis for Revision of Embrittlement Criteria in 10 CFR 50.46".	ML081350225.
September 24, 2008	Public Meeting Summary	ML083010496.
February 23, 2009	Plant Safety Assessment of RIL 0801	ML090340073.
July 31, 2008	**Federal Register** Notice (73 FR 44778), "Notice of Availability and Solicitation of Public Comments on Documents Under Consideration To Establish the Technical Basis for New Performance-Based Emergency Core Cooling System Requirements".	Reference the **Federal Register** at 73 FR 44778.
March 30, 2009	Supplemental research material—additional PQD tests.	ML090690711.
March 30, 2009	Supplemental research material—additional breakaway testing.	ML090700193.
March 31, 2009	Draft proposed procedure for Conducting Oxidation and Post-Quench Ductility Tests With Zirconium-based Cladding Alloys.	ML090900841.
March 23, 2009	Draft proposed procedure for Conducting Breakaway Oxidation Tests With Zirconium-Based Cladding Alloys.	ML090840258.
January 8, 2009	Update on Breakaway Oxidation of Westinghouse ZIRLO Cladding.	ML091330334.
May 7, 2009	Impact of Specimen Preparation on Breakaway Oxidation (Non-Proprietary).	ML091350581.

List of Subjects in 10 CFR Part 50

Antitrust, Classified information, Criminal penalties, Fire protection, Intergovernmental relations, Nuclear power plants and reactors, Radiation protection, Reactor siting criteria, Reporting and recordkeeping requirements.

The authority citation for this document is 42 U.S.C. 2201.

Dated at Rockville, MD, this 29th day of July 2009.

For the Nuclear Regulatory Commission.

R.W. Borchardt,

Executive Director for Operations.

APPENDIX A

An Approach for Determining the Acceptability of Zirconium-Based Cladding Alloys: Analytical Limits Defined Within Regulatory Guidance

This approach would include a future regulatory guidance document that defines an acceptable, generically-applicable set of analytical limits for peak cladding temperature and maximum allowable time-at-temperature (expressed as calculated local oxidation, CP–ECR) as a function of pre-transient hydrogen content in the cladding metal (excluding hydrogen in the cladding oxide layer). These acceptable analytical limits would be developed using NRC's empirical database with consideration of experimental variability and repeatability. Figure A shows the results of ring-compression tests conducted on as-fabricated, hydrogen charged, and irradiated specimens of Zircaloy-2, Zircaloy-4, ZIRLO™ and M5 cladding material (documented in NUREG/CR–6967). Note that hydrogen concentrations were slightly adjusted (± 5 wppm) to illustrate results of multiple ring-compression tests run at the same CP–ECR and hydrogen concentration. Peak oxidation temperature is identified for samples tested below 2200 °F (1204 °C).

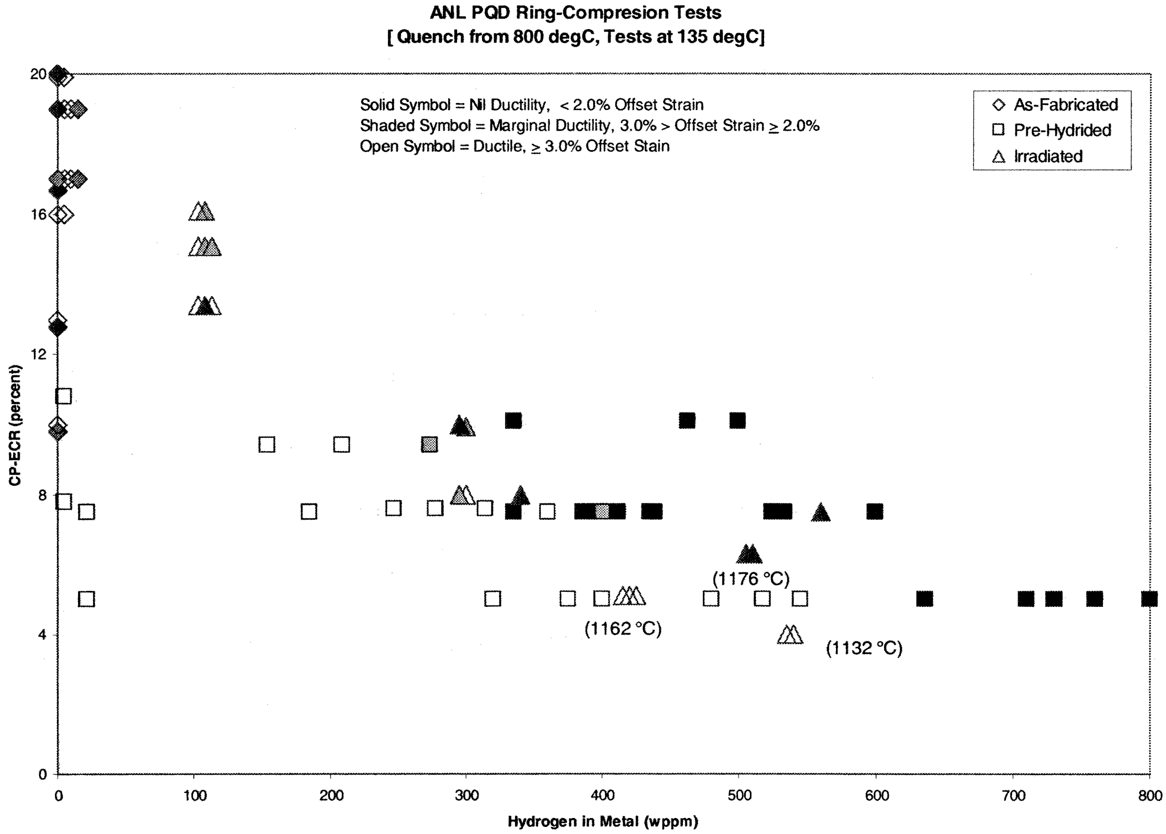

Figure A – Ring compression test results from as-fabricated, pre-hydrided and irradiated material. Samples were oxidized at ≤1200 ºC and quenched at 800 ºC. For high-burnup cladding with about 550 wppm hydrogen, embrittlement occurred during the heating ramp at 1160-1180 ºC peak oxidation temperatures. Peak oxidation temperatures are indicated.

The analytical limit on PCT would be restricted to the peak oxidation temperature during testing of the cladding specimens used in the development of this limit. Furthermore, caveats on the applicability of the analytical limits may be required to capture limiting aspects of the steam oxidation temperature profile used during the testing. For example, if the calculated time at the specified PCT is less than the time at peak oxidation temperature of the supporting empirical database (for a given CP–ECR), or the calculated quench temperature is lower than 800 °C, then an applicability caveat may be required.

Existing Cladding Alloys

No PQD testing would be required to approve cladding alloys included in the NRC's LOCA research program. Under this approach, a fuel vendor would submit a topical report (TR) seeking NRC approval of each zirconium-based cladding alloy's analytical limits on PCT and time-at-temperature (CP–ECR, as a function of cladding hydrogen content). The TR would reference the acceptable analytical limits within the Regulatory Guide.

New Cladding Alloys

Under this approach, a fuel vendor would submit a TR which demonstrates that the results of PQD tests on a specific new alloy are applicable to the acceptable analytical limits defined within the Regulatory Guide. A TR would need to include the results of testing, conducted in accordance with NRC's acceptable experimental methodology, which demonstrates that the embrittlement behavior of the new cladding alloy is consistent with the embrittlement behavior of the cladding alloys tested in NRC's LOCA research program by comparing test results to the defined analytical limit. This would likely require testing of the new cladding alloy with varying hydrogen contents, which are oxidized to calculated oxidation levels (CP–ECR) at or near the analytical limit for that hydrogen level as provided in regulatory guidance. Demonstrating ductile behavior in cladding samples with calculated oxidation levels at or near the analytical limit may serve to confirm the applicability of the analytical limit to a new cladding alloy. The range of hydrogen contents in test samples required may be limited by proposing cladding hydrogen design limits based on hot cell examinations of irradiated samples of the new cladding alloy following lead test assembly campaigns. Regulatory guidance would be provided to address the variability in measured offset strain of ring-compression test results. Section IV of this ANPR specifically seeks comment on the treatment of variability in ductility measurements of ring-compression tests.

For this description, it is assumed that sufficient justification for the use of hydrogen charged cladding specimens has been accepted as a surrogate for testing on irradiated cladding segments. If sufficient justification for the use of hydrogen charged cladding specimens has not been accepted as a surrogate for testing on irradiated cladding segments, approving new cladding alloys would require PQD testing of irradiated material. Section IV of this ANPR requests information on any ongoing or planned testing aimed at validating this pre-hydrided surrogate.

APPENDIX B

An Approach for Determining the Acceptability of Zirconium-Based Cladding Alloys: Cladding-Specific Analytical Limits Defined by an Applicant

This approach involves establishing cladding-specific and/or temperature-specific analytical limits for peak cladding temperature and maximum allowable time-at-temperature (expressed as calculated local oxidation, CP–ECR) as a function of pre-transient hydrogen content in the cladding metal (excludes hydrogen in the cladding oxide layer). This approach would provide optimum flexibility for defining more specific analytical limits to gain margin to the ECCS performance criteria. However, unlike citing analytical limits within a regulatory guide, this approach places the burden of proof on the applicant to validate their analytical limits and address experimental variability and repeatability. As a result, this approach would necessitate a larger number of PQD tests (relative to confirming the applicability of the regulatory guide). Analytical limits, along with the experimental procedures, protocols, and specimen test results used in their development, would be subject to NRC review and approval.

This approach would require that the PQD test results on irradiated cladding segments documented in NUREG/CR–6967 be considered in the development of analytical limits. Deviations in cladding performance relative to this empirical database must be identified and dispositioned.

Existing Cladding Alloys

In the case of existing cladding alloys, the rule may specify the following performance requirement to ensure an adequate retention of cladding ductility:

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 on a cladding specimen exposed to double-sided steam oxidation up to a specified peak oxidation temperature and CP–ECR.

Analytical limits on allowable time-at-temperature (CP–ECR) and peak cladding temperature would need to be defined as a function of initial cladding hydrogen content (wppm in metal) to demonstrate this performance requirement is met. A topical report (TR) would be generated to document the basis for the new analytical limits. Existing alloys which were included in the NRC high-burnup research program may reference the test results documented in NUREG/CR–6967 in the development of new analytical limits. This data was generated following experimental protocols acceptable to the NRC, so no further justification related to its validity would be required.

Using an approved hydrogen uptake model for an existing cladding alloy, the TR would provide the methodology to convert the hydrogen-based analytical limits to some unit of measure more readily applied within reload safety analyses (*e.g.,* fuel rod burnup or fuel duty). Uncertainties related to hydrogen uniformity and uncertainties introduced by the conversion from hydrogen to another unit of measure would need to be addressed.

New Cladding Alloys

In the case of new cladding alloys, the rule may specify the following performance requirement to ensure an adequate retention of cladding ductility:

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 on a cladding specimen exposed to double-sided steam oxidation up to a specified peak oxidation temperature and CP–ECR.

Analytical limits on allowable time-at-temperature (CP–ECR) and peak cladding temperature would need to be defined as a function of initial cladding hydrogen content (wppm in metal) to demonstrate this performance requirement is met. A TR would be generated to document the basis for the new analytical limits. The PQD test results on irradiated cladding segments documented in NUREG/CR–6967 would need to be considered in the development of analytical limits. PQD testing would be required to (1) establish analytical limits in accordance with the performance requirements that would be specified within the rule, and (2) demonstrate the applicability of the NUREG/CR–6967 empirical database. A TR could document that the PQD testing had been conducted to strictly adhere to the accepted experimental protocols documented in regulatory guidance documents, or if alternative testing procedures were used, then NRC review and approval of those laboratory procedures would be required.

For this approach, defining analytical limits for new cladding alloys would likely require testing at a range of hydrogen contents, with ring-compression test results at multiple calculated oxidation levels. Test samples with calculated oxidation levels sufficient to display brittle behavior, as well as test samples with calculated oxidation levels which display ductile behavior, would be necessary to define the transition from ductile to brittle behavior. Regulatory guidance would be provided to address the variability in measured offset strain of ring-compression test results. Section IV of this ANPR specifically seeks comment on the treatment of variability in ductility measurements of ring-compression tests. The range of hydrogen contents in test samples required may be limited by proposing cladding hydrogen design limits based on hot cell examinations of irradiated samples of the new cladding alloy following lead test assembly campaigns.

Multifaceted Analytical Limits

Recognizing that higher burnup fuel rods (with higher hydrogen concentrations) operate at a reduced power level (relative to lower burnup fuel rods), defining analytical limits for maximum allowable ECR at multiple peak oxidation temperatures would also be possible. For example, a TR could document the results of testing conducted at peak oxidation temperatures of 2200 °F (1204 °C), 2000 °F (1093 °C), and 1800 °F (982 °C), which are targeted at low burnup (low corrosion), medium burnup (medium corrosion), and high burnup (high corrosion) fuel rods, respectively. Testing to support these new limits would require testing at a range of hydrogen contents, with ring-compression test results at multiple calculated oxidation levels to define the transition from ductile to brittle behavior. In this case, it may be necessary to elect to strictly adhere to the accepted experimental protocols documented in regulatory guidance documents, thereby limiting regulatory exposure related to testing procedures and the validity of the data.

Implementation of the multifaceted analytical limits would require separating all of the fuel rods in the core into three categories and then ensuring that all fuel rods within each category satisfies their respective analytical limits on both CP–ECR and PCT. While it is anticipated that this approach would provide flexibility, it would also necessitate a more complex LOCA analysis and reload-by-reload confirmation. This approach also relies on tacit assumptions regarding the currently approved LOCA model's ability to accurately simulate the thermal-hydraulic conditions in every region of the reactor core (as opposed to simulating a core average response or pseudo hot channel location). Modeling uncertainties with respect to predicting local conditions throughout the reactor core would need to be addressed.

Using an approved hydrogen uptake model for a new cladding alloy, the TR would need to provide the methodology to convert the hydrogen-based analytical limits to some unit of measure more readily applied within reload safety analyses (*e.g.,* fuel rod burnup or fuel duty). Uncertainties related to hydrogen uniformity and uncertainties introduced by the conversion from hydrogen to another unit of measure would need to be addressed.

For this description, it is assumed that sufficient justification for the use of hydrogen charged cladding specimens has been accepted as a surrogate for testing on irradiated cladding segments. If sufficient justification for the use of hydrogen charged cladding specimens has not been accepted as a surrogate for testing on irradiated cladding segments, approving new cladding alloys would require PQD testing of irradiated material. Section IV of this ANPR requests information on any ongoing or planned testing aimed at validating this pre-hydrided surrogate.

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DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration

14 CFR Part 39

[Docket No. FAA–2009–0713; Directorate Identifier 2007–NM–303–AD]

RIN 2120–AA64

Airworthiness Directives; Airbus Model A318 Series Airplanes

AGENCY: Federal Aviation Administration (FAA), DOT.

ACTION: Notice of Proposed Rulemaking (NPRM).

SUMMARY: We propose to adopt a new airworthiness directive (AD) for the products listed above. This proposed AD results from mandatory continuing airworthiness information (MCAI) originated by an aviation authority of another country to identify and correct an unsafe condition on an aviation product. The MCAI describes the unsafe condition as:

Some operators have reported airframe vibration under specific flight conditions including gusts.

Investigations have revealed that under such conditions, vibrations may occur when