[7590-01-P]

NUCLEAR REGULATORY COMMISSION

10 CFR Part 50

Docket No. PRM-50-84

[NRC-2007-0013]

Mark Edward Leyse;
Consideration of Petition in Rulemaking Process

AGENCY: Nuclear Regulatory Commission.

ACTION: Resolution of petition for rulemaking and closure of petition docket.

SUMMARY: The Nuclear Regulatory Commission (NRC) will consider the issues raised in a petition for rulemaking (PRM) submitted by Mark Edward Leyse in the NRC's rulemaking process. The petition was dated March 15, 2007, and was docketed as PRM-50-84. The petitioner requests that the NRC amend its regulations to require that nuclear power reactors be operated in a manner to limit the thickness of crud layers and/or the thickness of oxide layers on fuel rod cladding surfaces to ensure that the facilities operate in compliance with the emergency core cooling system (ECCS) acceptance criteria. The petitioner also requests that the requirements pertaining to ECCS evaluation models be amended to explicitly require that the steady-state temperature distribution and stored energy in reactor fuel at the onset of a postulated loss-of-coolant accident (LOCA) be calculated by factoring in the role that the thermal resistance of crud and/or oxide layers on fuel cladding plays in increasing the stored energy of the fuel. Lastly, the petitioner requests that the acceptance criteria for analyses of ECCS cooling performance for light-water nuclear power reactors be amended to stipulate a maximum allowable percentage of hydrogen content in the cladding of fuel rods. The NRC will consider the petitioner's first two requests in PRM-50-84 because the underlying technical

considerations regarding the effects of crud and oxide growth on ECCS analyses noted by the petitioner are sufficiently related to an ongoing NRC rulemaking activity on ECCS analysis acceptance criteria. The NRC will consider the petitioner's third request because the NRC has already initiated rulemaking activities that will address the petitioner's underlying technical concerns on fuel cladding embrittlement.

While the NRC will consider the issues raised in the petition in its rulemaking process, the petitioner's concerns may not be addressed exactly as the petitioner has requested. During the rulemaking process, the NRC will solicit comments from the public and will consider all comments before issuing a final rule.

DATES: The docket for the petition for rulemaking PRM-50-84 is closed on **[Insert date of publication in the Federal Register].**

ADDRESSES: You can access publicly available documents related to this petition for rulemaking using the following methods:

Federal e-Rulemaking Portal: Documents related to the evaluation of this petition are assigned to rulemaking docket ID: NRC-2006-0013. Further NRC action on the issues raised by this petition will be considered in the rulemaking to establish Performance-based ECCS Cladding Acceptance Criteria, (RIN 3150-AH42) which has been assigned rulemaking docket ID: NRC-2008-0332. Information on this petition and the related rulemaking can be accessed at the Federal rulemaking portal, http://www.regulations.gov; search on rulemaking docket ID: NRC-2007-0013 and NRC-2008-0332. The NRC also tracks all rulemaking actions in the "NRC Regulatory Agenda: Semiannual Report (NUREG-0936)."

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.

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 1-800-397-4209, 301-415-4737 or by e-mail to PDR.resource@nrc.gov .

FOR FURTHER INFORMATION CONTACT: Richard Dudley, Mail Stop O12-D3, Office of Nuclear Reactor Regulation, United States Nuclear Regulatory Commission, Washington, DC 20555-0001; telephone (301) 415-1116, or e-mail richard.dudley@nrc.gov.

SUPPLEMENTARY INFORMATION:

The Petition

The NRC received a petition for rulemaking (ADAMS Accession No. ML070871368) from Mark Edward Leyse (the petitioner) dated March 15, 2007, 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 and/or oxide layers on fuel rod cladding surfaces. On May 23, 2007, the NRC published a notice of receipt for this petition in the Federal Register (72 FR 28902) and requested public comment. The public comment period ended on August 6, 2007.

NRC Evaluation

The NRC review of this petition and evaluation of public comments are based upon NRC's understanding of several terms used by the petitioner:

1. Crud is any foreign substance which may become deposited on the surface of fuel cladding. This layer can impede the transfer of heat. The NRC believes that the word “crud” originated as an acronym for “Chalk River Unidentified Deposit”, based upon deposits on early test fuels observed at Chalk River Laboratories in Canada. Crud most frequently refers to deposits of tiny iron or nickel metallic particles eroded from pipe and valve surfaces. These particles of stable isotopes may become "activated" or irradiated and transform into radioactive isotopes, such as cobalt-60. In fouling technology today, the term "crud" is generally applied to solid deposits on fuel element heat transfer surfaces (cladding). The NRC staff makes a clear 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 when the cladding material reacts with oxygen.

2. Oxide is a product of the reaction of oxygen with the zirconium cladding material itself. Zirconia, or zirconium dioxide (ZrO_2) is one oxidation product which may be found on the exterior surface (and sometimes the interior surface) of zirconium fuel cladding. Although it may be an additional surface layer, formation of oxides also consumes some cladding base material, thereby decreasing metal cladding thickness. Compared to the original metal cladding material, metal oxides usually are more brittle and conduct heat less effectively. In this discussion, the terms “corrosion” and “oxidation” are considered one and the same.

3. Hydrogen in a nuclear reactor may be produced by the break up of coolant water molecules during the oxidation process described previously. Hydrogen may not only be present in the reactor coolant, but may also diffuse into the fuel cladding. It may then either remain in solution or be precipitated as a zirconium hydride. Hydrogen in either form has been found to alter both the material properties and behavior of the cladding

material. Formation of zirconium hydrides, such as ZrH_2, has been found to cause embrittlement of zirconium fuel cladding.

The NRC understands the petitioner as requesting the NRC to conduct rulemaking in 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 10 CFR 50.46(b) ECCS acceptance criteria;

2. Amend current regulations in 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 calculations); and

3. Amend § 50.46 to specify a maximum allowable percentage of hydrogen content in cladding.

The NRC will address each of the petitioner's requests below. The NRC will first address the petitioner's third request because the logic used to evaluate the other requests can be more easily understood.

Proposal 3 - Amendment of 10 CFR 50.46, Acceptance Criteria for Emergency Core Cooling Systems for Light-water Nuclear Power Reactors, to include a limit on maximum hydrogen content in cladding.

The petitioner states that an increase in hydrogen content in cladding contributes to cladding embrittlement. The petitioner cites an April 4, 2001, NRC Advisory Committee on Reactor Safeguards (ACRS) subcommittee meeting on reactor fuels during which an expert

from Argonne National Laboratory stated that a reduction of ductility occurs when hydrogen levels reach about 600 to 700 parts-per-million (ppm) in Zircaloy cladding. According to the petitioner, another expert from the Atomic Energy Research Institute stated that a threshold for a reduction of ductility in Zircaloy cladding occurs at even a lower hydrogen level of about 150 to 200 ppm. The petitioner also references an event at Three Mile Island, Unit 1 (TMI-1) during refueling Cycle 10 that involved hydrogen absorption in fuel cladding. The petitioner notes that hydrogen content in the cladding of a rod that did not fail measured 700 ppm at TMI-1 and that this level of hydrogen content in one-cycle cladding is similar to the 800 ppm level measured in fuel cladding at the H.B. Robinson, Unit 2 facility, a pressurized water reactor (PWR). The petitioner states that some of the cladding in TMI-1 Cycle 10 contained levels of hydrogen that Argonne National Laboratory found would have caused a loss of cladding ductility in addition to the embrittlement resulting from excessive oxide levels.

The petitioner also states that absorption of hydrogen would contribute to a loss of cladding ductility during a LOCA along with cladding degradation and massive oxidation. The petitioner cites a failed fuel rod from the TMI-1, Cycle 10 event when hydrogen absorption caused hydrided material to break away from the outer portions of the cladding. The petitioner believes that the effects of increased stored energy due to a heavy crud layer in the fuel and the severity of cladding oxidation, embrittlement, and resulting fuel degradation during an actual event would be substantially greater than in an ECCS calculation based on clean cladding.

In 2003, the Commissioners directed the NRC staff to undertake rulemaking to amend 10 CFR 50.46 to provide for a more performance-based approach to meeting the ECCS acceptance criteria in § 50.46(b). Technical work to finalize the technical basis for this rulemaking is currently proceeding and includes a study (Research Information Letter 0801, “Technical Basis for Revision of Embrittlement Criteria in 10 CFR 50.46,” May 30, 2008, ADAMS accession no. ML081350225; NUREG/CR-6967, “Cladding Embrittlement During

Postulated Loss-of-Coolant Accidents," July 2008, ADAMS accession no. ML082130389) of the effects on cladding embrittlement caused by cladding oxidation and hydrogen. Because the NRC is already investigating the need to amend § 50.46 to address hydrogen effects on cladding, the petitioner's request in Proposal 3 will be considered during the current rulemaking. This rulemaking is designated as RIN 3150-AH42 in the "NRC Regulatory Agenda: Semiannual Report (NUREG-0936)." Documents associated with this rule are posted under docket ID: NRC-2008-0332 on the Regulations.gov website. Rulemaking will begin when a consensus is reached on the technical basis for the amendments.

Proposal 1 - Establish regulations that require licensees to operate light water power reactors under conditions that effectively limit the thickness of crud and oxide layers on zirconium-clad fuel to ensure compliance with 10 CFR 50.46(b) ECCS acceptance criteria.

To support the rulemaking request in Proposal 1 of the petition, the petitioner lists sources, such as the Electric Power Research Institute (EPRI) reports, ACRS transcripts, and several journal articles to show that the thermal conductivities of the crud and oxide layers are lower than the thermal conductivity of zirconium metal cladding. The petitioner asserts that because of these lower heat transfer rates, the stored energy within the fuel and the time to transfer stored energy will increase. The petitioner cites several operating instances to support the contention that safety issues can arise from the thermal resistance of crud and oxide layers on fuel cladding. Finally, the petitioner lists several examples to show that incidents of fuel failures have increased in recent years.

The petitioner's request in Proposal 1 is founded on the potential impact of crud and oxide on ECCS performance evaluations. The NRC generally agrees with the petitioner that crud and oxide formation can impact the thermal response of the fuel system. Hydrogen embrittlement is also an issue in the ongoing rulemaking to revise the ECCS acceptance criteria discussed in Proposal 3 above. The need for any operational restrictions, as requested by the

petitioner, would presumably be determined (in part) from these considerations. The NRC believes that the petitioner's Proposal 1 is sufficiently relevant to the ongoing cladding embrittlement rulemaking to warrant consideration in that proceeding. The NRC is accepting the petitioner's Proposal 1 for consideration during the current rulemaking to revise § 50.46(b). In deciding to consider the petitioner's concern in the § 50.46(b) rulemaking, the NRC expresses no position on the specific merits of the petitioner's request and underlying bases. These issues will be addressed separately as part of the rulemaking.

Proposal 2 - Amendment of Appendix K to 10 CFR Part 50, ECCS Evaluation Models I(A)(l), The Initial Stored Energy in the Fuel, to also require the thermal resistance of crud deposits and/or oxide layers as factors in calculations of steady-state temperature distribution and stored energy in the reactor fuel at the onset of a postulated LOCA.

In this proposal, the petitioner requested that Appendix K to 10 CFR Part 50 be amended to include explicit instructions on how to perform the ECCS performance calculations mentioned above. Also, in lieu of Appendix K calculations, the petitioner requested establishment of a regulation stating that these requirements must also apply to any NRC-approved, best-estimate ECCS evaluation model, as described in NRC Regulatory Guide 1.157. The petitioner states that because layers of crud and/or oxide increase the quantity of stored energy in the fuel, Appendix K to Part 50 should explicitly require that the thermal conductivity of layers of crud and/or oxide be factored into calculations of the stored energy in the fuel. In support of the petition, several references are cited. For example, the petitioner quotes from a letter to the NRC from James F. Klapproth, Manager, Engineering and Technology at General Electric Nuclear Energy (April 8, 2002, ADAMS accession no. ML021020383): "The primary effects of [a] heavy crud layer during a postulated LOCA would be an increase in the fuel stored energy at the onset of the event, and a delay in the transfer of

that stored energy to the coolant during the blowdown phase of the event."

Proposal 2 requests that Appendix K explicitly require consideration of crud and/or oxide layers in the calculation of stored energy used in ECCS performance calculations required by § 50.46. Appendix K provides requirements for one acceptable methodology for performing § 50.46 ECCS performance calculations that must meet the acceptance criteria in § 50.46(b). Similar to Proposal 1 above, the petitioner's request in Proposal 2 is founded on the potential impact of crud and oxide on ECCS performance evaluations. Because the NRC agrees with the petitioner that crud and oxide formation can change the thermal response of the fuel system, it is possible that crud and oxidation layers could also have an impact on cladding hydrogen concentration. Also, because hydrogen uptake and concentration are being considered in the ongoing rulemaking to establish new performance-based ECCS acceptance criteria, consideration of crud and oxidation in that context is appropriate. Thus, the NRC concludes that Proposal 2 is likewise sufficiently relevant to the ongoing rulemaking to warrant consideration in that proceeding. As in the case of the petitioner's Proposal 1, the NRC expresses no position on the specific merits of the petitioner's Proposal 2 and its underlying bases. These issues will be addressed separately as part of the § 50.46(b) rulemaking.

Comparison of PRM-50-84 with Previous Similar Petitions

PRM-50-84 is the fifth in a series of petitions for rulemaking submitted to the NRC regarding the build-up, analysis, and release of crud on nuclear power plant heat exchange surfaces, and the oxidation of zirconium fuel cladding. Each of the four previous petitions (PRM-50-73 and PRM-50-73A (68 FR 41963; July 16, 2003); PRM-50-76 (70 FR 52893; September 9, 2005); and PRM-50-78 (69 FR 56958; September 23, 2004) have been denied by the Commission. The NRC evaluated each of the previous petitions and concluded that the requested actions would not contribute to maintaining the public safety or security, nor would it

improve the regulatory efficiently and effectiveness. The current petition is being considered because it includes the assertion that the accumulation of crud and oxide deposits will interfere with effective heat exchange between the cladding and coolant, increase fuel temperatures, and thus, lead to safety problems. Additionally, the NRC's knowledge of the effects of crud, oxidation, and hydrogen content on cladding integrity has increased in the last few years.

In 2003, the NRC initiated work to develop the technical basis for new, performance-based ECCS acceptance criteria that would apply to all zirconium cladding alloys[1]. Laboratory testing was performed on non-irradiated and irradiated zirconium alloys with different burnups to determine what parameters affected cladding embrittlement. On May 30, 2008, the NRC summarized the results of this research effort in a letter (Research Information Letter 0801, "Technical Basis for Revision of Embrittlement Criteria in 10 CFR 50.46," May 30, 2008, ADAMS accession no. ML081350225). The NRC is now evaluating this information to determine if it provides an adequate basis for establishing the new, performance-based ECCS acceptance criteria. Two significant conclusions of this work are that hydrogen content of cladding is an important factor in causing cladding embrittlement and that cladding oxidation is a key contributor to cladding hydrogen content. Because crud and oxide formation can impact the thermal response of the fuel system, it is possible that crud and oxidation layers could also have direct or indirect impacts on cladding hydrogen concentration. Also, because all these factors appear to be interrelated, the NRC will consider all of the phenomena addressed in PRM-50-84 (crud, oxidation, and hydrogen content) in the ongoing rulemaking to establish new performance-based ECCS acceptance criteria in § 50.46(b).

Analysis of Public Comments

[1] The acceptance criteria in the current regulations are specifically applicable to only two cladding alloys, Zircaloy and Zirlo. Fuel designs with other, more advanced cladding alloys must be reviewed on a case-by-case basis and require NRC approval of an exemption to the existing requirements.

Comments in support of PRM-50-84 were provided by the Union of Concerned Scientists (UCS), two individuals, and the petitioner. The Nuclear Energy Institute and Strategic Teaming and Resource Sharing organization submitted comments in opposition to the petition. A summary of the comments and the NRC's evaluation of those comments follow.

Comment: A commenter referenced various technical reports and operational events to demonstrate that the accumulated hydrogen content of zirconium fuel cladding reduces the ductility of the cladding and increases the possibility that core geometry could change during a LOCA and reduce fuel cooling. (MEL 7-1)

NRC Response:

The NRC agrees with the commenter that cladding ductility can be reduced by hydrogen absorption in zirconium cladding. Since 2003, the NRC has been working to develop the technical basis for a new regulation on performance-based ECCS acceptance criteria applicable to the various zirconium cladding alloys. The NRC accepts this aspect of the petitioner's request and will consider hydrogen embrittlement issues during the ongoing rulemaking.

Comment: Several commenters referred to numerous technical reports, papers, and articles to document the existence of crud and oxidation layers on light-water reactor fuel cladding and show that the thermal resistance associated with the crud and oxidation layers significantly affects fuel temperatures and ECCS performance. (RHL-1, RHL-2, MEL 6-1, MEL 6-2, MEL 7-1, MEL 7-2, MEL 7-3, RHL 8-2, RHL-10)

NRC Response:

The NRC reviewed the technical information provided or referenced by the commenters. The NRC agrees with the commenters that formation of cladding crud and oxide layers is an expected condition at nuclear power plants. However, the amount of accumulated crud and

oxidation varies from plant to plant and from one fuel cycle to another. The NRC agrees that crud and/or oxide layers may directly affect the stored energy in the fuel by their thermal resistance as well as indirectly affecting the stored energy through an increase in the fuel rod internal pressure. In addition to the thermal insulating effect of crud, the NRC notes that a crud layer can also change surface topography, which has also been shown to affect cladding oxidation. As part of the ongoing rulemaking on performance-based ECCS analysis acceptance criteria, the NRC will evaluate the effects of these phenomena on cladding hydrogen content and embrittlement to determine their overall significance and if the regulations should be amended in this area.

Comment: A commenter asserted that the need to implement PRM-50-84 is shown by analysis of the NRC's February 28, 2006, inspection report on the River Bend Station (ML060600503). The inspection reviewed activities conducted by the licensee related to the identification and resolution of problems, including calculated higher cladding temperatures in fuel Cycle 8 and the formation of tenacious crud on the fuel rod cladding and fuel rod bowing in River Bend Cycle 11. (RHL-2)

NRC Response:

The NRC agrees with the commenter that the River Bend experience shows that exceptionally large accumulations of oxide and crud can have an impact on thermal hydraulic analyses. As part of the ongoing rulemaking on performance-based ECCS analysis acceptance criteria, the NRC will evaluate: (i) the effects of these phenomena on cladding hydrogen content and embrittlement to determine their overall significance, (ii) if such large accumulations are likely to occur under current NRC requirements and industry practices, and (iii) if the NRC's requirements should be amended in this area.

Comment: Thermal-hydraulic analyses of ECCS performance approved by the NRC are often inadequate because they may not consider or improperly consider the thermal resistance

of accumulated crud and/or oxidation on fuel cladding. Commenters cited examples of plant-specific ECCS analyses and asserted that had crud been properly considered, it is likely that the licensee would not be in compliance with the ECCS analysis acceptance criteria in § 50.46(b). (RHL-2, MEL 7-1, MEL 7-2, MEL 7-3)

NRC Response:

Assertions regarding potentially non-compliant ECCS analyses at the facilities mentioned are issues which are separate from resolving a petition for rulemaking on the adequacy of existing regulations. These assertions are not appropriate for consideration in a rulemaking context and are outside the scope of review of this PRM. This information has been referred to the Office Allegation Coordinator to determine the need for additional plant-specific regulatory review.

Comment: A commenter cited Generic Safety Issue No. 191 (GSI-191) regarding pressurized water reactors (PWRs), "Assessment of Debris Accumulation on PWR Sump Performance," and a related document, "Peer Review of GSI-191 Chemical Effects Research Program" (NUREG-1861), as justification for the petitioner's conclusion that the current regulations in § 50.46 should be amended. The commenter asserts that these documents discuss the possibilities of incomplete modeling of crud-related thermal properties of fuel cladding. (UCS 3-4)

NRC Response:

In GSI-191, the NRC is addressing issues involving PWR containment sump performance and related chemical effects during a loss-of-coolant accident. The GSI-191 issues are different from the long-term buildup of crud and oxidation on reactor fuel which typically occurs during plant operation. The NRC agrees with the commenter that dissolved solids in post-accident cooling water that impinges on hot fuel surfaces could be deposited or

precipitated out and could impede heat transfer from the fuel. The evaluation of GSI-191 by the NRC is a separate issue.

Comment: A commenter identified two distinguishable layers in BWR fuel cladding deposits: an inner spinel structure and an outer iron oxide structure. The commenter further described the use of zinc in the coolant chemistry of some reactors to reduce radiation buildup on out-of-core surfaces and stated that the potential culprit in cladding overheating could be the tenacious ferrite deposit. Because the thermal conductivity of the ferrite is not known, the commenter concluded that the potential effects of the tenacious layer should be seriously evaluated. (LIN-4)

NRC Response:

The NRC has considered the comment and agrees with much of the information provided. The structure and the composition of crud deposits may be complex. Also, the relationship between crud deposition and coolant chemistry is difficult to completely characterize. As part of the ongoing rulemaking on performance-based ECCS analysis acceptance criteria, the NRC will evaluate the effects of these phenomena on cladding hydrogen content and embrittlement to determine their overall significance and if the regulations should be amended in this area.

Comment: A commenter referred to an NRC press release regarding an order issued to First Energy Nuclear Operating Company. The order addresses the prompt sharing of information that may be relevant to regulatory activities. The commenter asserted that a proprietary EPRI report, “BWR Fuel Deposit Sample Evaluation, River Bend Cycle 11 Crud Flakes,” has information relevant to regulatory activities associated with PRM-50-84. The commenter implied that the River Bend Station licensee should be subject to a similar NRC order requiring that it provide information, such as the EPRI report, to the NRC. (RHL-9)

NRC Response:

The NRC reviewed the information about River Bend Cycle 11 provided by the petitioner and commenters and the inspection report (ML060600503) prepared by the NRC inspection team that investigated the crud occurrences in River Bend Cycles 8 and 11. Although the NRC inspection report referenced the proprietary EPRI report, the NRC staff evaluating PRM-50-84 did not review the EPRI report. Nevertheless, the NRC agrees with the commenter that the River Bend experience shows that exceptionally large accumulations of oxide and crud can have an impact on thermal hydraulic analyses. As part of the ongoing rulemaking on performance-based ECCS analysis acceptance criteria, the NRC will evaluate the effects of these phenomena on cladding hydrogen content and embrittlement to determine their overall significance and if the regulations should be amended in this area.

Comment: A commenter opposed granting the petition because the petition relies heavily on abnormal operating experiences at four plants: River Bend (1998-1999 and 2001-2003), Three Mile Island 1 (1995), Palo Verde Unit 2 (1997), and Seabrook (1997), when localized sections of thick crud developed during normal operation. The commenter stated that NRC guidelines in Section 4.2 of the Standard Review Plan (NUREG-0800) do not specify a specific limit on the maximum allowable corrosion thickness, but require the impact of corrosion on the thermal and mechanical performance to be considered in fuel design analysis regarding the design stress and strain limits.

The commenter stated that cladding hydrogen content can have an adverse effect on ductile/brittle behavior of zirconium alloys heated into the beta phase and quenched (as would occur in a LOCA). The hydrogen impact on post-quench cladding ductility is a complex function of the oxidation temperature and pre-quench cooling path. The potential impact of hydrogen on the § 50.46(b) fuel acceptance criteria has been recognized for several years. Experimental programs are underway to assess this impact on current and newer cladding alloys developed

to minimize hydrogen build-up during irradiation. The commenter further states that, based on these data, the NRC Office of Nuclear Regulatory Research is developing the technical basis for new performance-based fuel acceptance criteria in § 50.46(b) that include the effects of hydrogen.

In summary, the commenter states 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. The industry is actively pursuing root cause evaluations and has developed corrective actions to mitigate further cases of excessive crud formation. The separate effects of hydrogen on cladding embrittlement will be addressed in future rulemaking to implement new acceptance criteria that are already being developed by the NRC. (NEI 5-1, NEI 5-2, NEI 5-3, NEI 5-4, NEI 5-5, NEI 5-6, NEI 5-7)

NRC Response:

The NRC agrees with a great deal of the technical information provided by the commenter and with the commenter's view that new regulations imposing specific regulatory limits on crud thickness would not necessarily have prevented the occurrences of heavy crud deposits resulting from the operational events cited by the petitioner. Nevertheless, formation of cladding crud and oxide layers is an expected condition at nuclear power plants. The thickness of these layers varies from plant to plant. The commenter acknowledged that the hydrogen impact on post-quench cladding ductility is a complex function of the oxidation temperature and pre-quench cooling path, and that these effects will be evaluated in the ongoing rulemaking to develop more performance-based cladding acceptance criteria. Because crud and oxide considerations also have potential impact on these new criteria, the NRC has determined that the petitioner's issues are sufficiently related to the ongoing cladding acceptance criteria rulemaking and should be considered in that proceeding.

Comment: Commenters stated that industry-funded research has resulted in chemistry controls, core design constraints, and operational guidance that reduce the susceptibility to heavy crud deposition and that many pressurized water reactors, especially those most susceptible to heavy crud deposition, make extensive use of the industry guidance. Commenters stated that the requested rulemaking would not make a significant contribution to safety because existing regulations and guidance already address consideration of crud-related parameters for core cooling. A commenter stated that NRC and licensee efficiency and effectiveness would be decreased by the requested regulations because significant resources would be required for the NRC to promulgate the rule, for licensees to generate additional information as part of the development of their ECCS evaluation models, and for the NRC to evaluate the licensees' data and analysis. (NEI 5-1, STARS 11-1, NEI 5-2, STARS 11-2, STARS 11-3)

NRC Response:

The NRC acknowledges that voluntary industry guidance, if properly implemented by licensees, can be effective in reducing the susceptibility to heavy crud deposition. However, the NRC has determined that crud and oxidation layers can have an impact on cladding hydrogen concentration. Because hydrogen uptake and concentration are being considered in the ongoing rulemaking to establish new performance-based ECCS acceptance criteria, consideration of crud and oxidation in that context is appropriate. If the NRC decides that additional regulations are needed regarding the accumulation of crud and oxidation, the NRC will estimate the additional NRC and licensee burden associated with the proposed changes and evaluate the overall cost-effectiveness of the requirements.

Late Comment: On September 5, 2008, after the close of the public comment period on PRM-50-84, the NRC received an additional public comment from Mr. Mark Leyse. The NRC reviewed the information contained in the late comment and determined that it provided no

additional information that would affect the NRC's decision to address the issues raised in PRM-50-84 in the ongoing § 50.46(b) rulemaking.

Resolution of Petition

The NRC will consider the petitioner's requested rulemaking changes, the underlying issues relevant to the petition, and the comments submitted on PRM-50-84, in the ongoing rulemaking to revise § 50.46(b). This rulemaking is directed at establishing performance-based ECCS acceptance criteria to prevent fuel cladding embrittlement. The petitioner's requested changes and the underlying issues address crud, oxidation, and hydrogen content. These parameters may be factors in hydrogen embrittlement of zirconium cladding, which is being addressed in the § 50.46(b) rulemaking. After the conclusion of the NRC's technical evaluation of the factors relevant to fuel cladding embrittlement, the NRC will determine whether to adopt the petitioner's requested rulemaking changes in the § 50.46(b) rule. If the ongoing work to establish the technical basis for this rulemaking does not support the issuance of a proposed rule, the NRC will issue a supplemental Federal Register notice that addresses why the petitioner's requested rulemaking changes were not adopted by the NRC. With this resolution of the petition, the NRC closes the docket for PRM-50-84.

Dated at Rockville, Maryland, this 5th day of November, 2008.

For the Nuclear Regulatory Commission.

/RA Martin J. Virgilio for/

Martin J. Virgilio
Acting Executive Director
for Operations.

additional information that would affect the NRC's decision to address the issues raised in PRM-50-84 in the ongoing § 50.46(b) rulemaking.

Resolution of Petition

The NRC will consider the petitioner's requested rulemaking changes, the underlying issues relevant to the petition, and the comments submitted on PRM-50-84, in the ongoing rulemaking to revise § 50.46(b). This rulemaking is directed at establishing performance-based ECCS acceptance criteria to prevent fuel cladding embrittlement. The petitioner's requested changes and the underlying issues address crud, oxidation, and hydrogen content. These parameters may be factors in hydrogen embrittlement of zirconium cladding, which is being addressed in the § 50.46(b) rulemaking. After the conclusion of the NRC's technical evaluation of the factors relevant to fuel cladding embrittlement, the NRC will determine whether to adopt the petitioner's requested rulemaking changes in the § 50.46(b) rule. If the ongoing work to establish the technical basis for this rulemaking does not support the issuance of a proposed rule, the NRC will issue a supplemental Federal Register notice that addresses why the petitioner's requested rulemaking changes were not adopted by the NRC. With this resolution of the petition, the NRC closes the docket for PRM-50-84

Dated at Rockville, Maryland, this 5th day of November, 2008.

For the Nuclear Regulatory Commission.

/RA Martin J. Virgilio for
Martin J. Virgilio
Acting Executive Director
for Operations.

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