Summary of Public Comments on Petition for Rulemaking PRM-50-84

Comment 1. Submitted July 27, 2007 by Robert H. Leyse **(RHL-1)**

The commenter asserts that the need to implement Proposed Rulemaking (PRM) PRM-50-84 is clearly illustrated by the Nuclear Regulatory Commission's (NRC's) incomplete evaluations of General Electric (GE) Licensing Topical Report NEDC-33006P, Revision 2, "General Electric Boiling Water Reactor Maximum Extended Load Line Limit Analysis Plus," (MELLLA+) and NEDC-33173P, "Applicability of GE Methods to Expanded Operating Domains." The commenter cites an Advisory Committee on Reactor Safeguards (ACRS) letter of June 22, 2007 (recorded in the NRC's Agencywide Documents Access and Management System (ADAMS) under accession number: ML071760346), which states that the staff did not have the thermal-hydraulic code capability to independently confirm some important parts of the evaluation such as Anticipated Transient Without Scram (ATWS) instability.

The commenter further asserts that the NRC evaluation of MELLLA+ is incomplete because it did not consider crud deposits. He also states that TRACE, a thermal-hydraulic system analysis code, has no specifications that incorporate the impact of crud deposits.

Comment 2. Submitted July 27, 2007 by Robert H. Leyse **(RHL-2)**

The commenter asserts that the need to implement PRM-50-84 is clearly illustrated by analysis of the NRC's February 28, 2006 inspection report on River Bend Station (ML060600503). The River Bend reactor is a boiling water reactor (BWR). 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 the River Bend Cycle 11 fuel.

The commenter stated that the reviewers of PRM-50-84 should study the River Bend inspection report and a proprietary Electric Power Research Institute (EPRI) report, "BWR Fuel Deposit Sample Evaluation, River Bend Cycle 11 Crud Flakes."

Comment 3. Submitted July 31, 2007 by David Lochbaum of the Union of Concerned Scientists (UCS)

A series of five comments are provided in support of PRM-50-84:

UCS 3-1: The commenter states that the petitioner provided a well-documented justification for the recommended changes to the regulations.

UCS 3-2: The commenter cites a September 23, 2005, letter from the Advisory Committee on Reactor Safeguards (ACRS) as evidence that, when new information is presented about a safety shortfall in the original requirements, the NRC must revise its regulations to reduce unnecessary risk.

UCS 3-3: The commenter cites General Design Criterion (GDC) 4 in Appendix A to the Code of Federal Regulations, Title 10, Chapter 1, Part 50 (10 CFR Part 50) as justification for PRM-50-84. This criterion addresses the accommodation of the effects of environmental conditions associated with normal operation and postulated accidents. The commenter states that PRM-50-84 is necessary to ensure that fuel cladding operates properly under these conditions.

UCS 3-4: The commenter cites Generic Safety Issue No. 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 PRM-50-84. The commenter asserts that these documents discuss the possibilities of incomplete modeling of crud related thermal properties of fuel cladding.

UCS 3-5: The commenter states that PRM-50-84 is necessary to explicitly state the regulatory requirements for accounting for crud and oxidation on fuel cladding during normal operation and postulated accidents in safety analyses. Further, the commenter states that the regulatory changes sought by this petition are necessary to provide reasonable assurance that public health and safety is adequately protected.

Comment 4. Submitted August 3, 2007 by C. C. Lin **(LIN-4)**

The commenter, a retired chemist who specialized in reactor coolant chemistry, identifies two distinguishable layers in BWR fuel cladding deposits: an inner spinel structure and an outer iron oxide structure. The commenter further describes the use of zinc in the coolant chemistry of some reactors to reduce radiation buildup on out-of-core surfaces. He states his view that the potential culprit in cladding overheating could be the tenacious ferrite deposit. He notes the difficulty in limiting crud input from BWR feedwater systems. He concludes that, since the thermal conductivity of the ferrite is not known, the potential effects of the tenacious layer should be seriously evaluated.

Comment 5. Submitted August 3, 2007 by James H. Riley of the Nuclear Energy Institute (NEI).

The commenter provides the following six specific reasons why the current regulations and staff guidance documents adequately specify the requirements to consider the impact of crud and/or corrosion layers resident on fuel rod cladding surfaces:

NEI 5-1: The commenter states that 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), where localized sections of thick crud developed during normal operation. The commenter further states that the nuclear Industry has taken corrective actions to develop revisions to existing water chemistry guidelines to mitigate both general and localized crud formation during operation.

NEI 5-2: The commenter states 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 they do 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 effects include:

(i) the heat transfer resistance provided by the oxide and crud layers, thereby increasing fuel temperatures, and

(ii) the metal loss due to corrosion, thereby reducing the cladding load carrying ability.

NEI 5-3: The commenter states that the impact of crud and oxidation may be determined either explicitly or implicitly in licensee fuel performance models approved by the NRC. Since the system of approved models is benchmarked to temperature and fission gas release data which inherently includes corrosion up to high burnup levels.

NEI 5-4: The commenter states that for the PWR cases of unusual crud deposits cited by the petitioner, post-cycle fuel inspection has shown no significant increase in overall cladding corrosion, thus cladding temperature was not significantly affected with the exception of a few localized sites. These sites are limited axially and azimuthally such that their thermal resistance effect on the overall fuel temperature and stored energy is small. Damage at these sites is no different than other types of cladding damage such as fretting or secondary hydriding of leaking rods. Thus, assuming that cladding with localized crud damage has failed using existing Standard Review Plan (SRP) section 4.2 acceptance criteria, the consequences associated with unusual crud deposits are no different than the other types of fuel rod failure modes already accounted for in the plant Technical Specification limits. Reactor coolant system iodine levels in plant TSs restrict the number of damaged rods in a core. The commenter states that, since crud-affected rods are not expected to have any significant effects on initial core conditions that could affect Loss of Coolant Accident (LOCA) consequences, the impact on LOCA analyses would be negligible.

NEI 5-5: The commenter states that, for the one BWR case cited (River Bend), significant increases in cladding corrosion in Cycle 8 were observed only in conjunction with unusually heavy tenuous crud formation. Such crud formation occurred only at lower elevations and would only affect initial stored energy at lower elevations. Although bundle flow would be reduced causing higher initial voiding in the upper part of these bundles, the effect is of secondary importance for a postulated LOCA and is within the envelope determined for core operations with reduced core flow. The commenter further states that calculated peak cladding temperature (PCT) in a BWR LOCA event is relatively insensitive to the initial stored energy because the PCT values that challenge the licensing limit occur later in the event and are dominated by the balance between the decay heat and the amount of steam cooling after the initial stored energy difference has been mitigated. Although a very early peak in calculated PCT is sensitive to stored energy, this value is seldom the most limiting value. When it is limiting, this peak is far from the licensing limit of 2,200^{o}F.

The commenter states that the crud anomaly in River Bend Cycle 11 is generally considered to have been less severe than Cycle 8 since the heavy crud deposition was even more localized. Both events were operational experiences and would not have been prevented or mitigated by the imposition of licensing limits on crud thickness. After the second event, River Bend implemented specific hardware changes based on the root-cause determination to prevent further high-crud events. These changes have been effective to date.

NEI 5-6: The commenter states 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 10 CFR § 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 (RES) is developing the technical basis for new performance-based fuel acceptance criteria in § 50.46(b) that include the effects of hydrogen.

NEI 5-7: In summary, NEI states that the incidents cited by the petitioner were isolated operational events and would not have been prevented by imposing specific 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 changes to acceptance criteria already being developed by the NRC.

Comment 6. Submitted August 5, 2007 by Mark Edward Leyse

MEL 6-1: The petitioner provides additional information to illustrate why the thermal resistance of the crud and/or oxide layers on fuel cladding must be addressed when determining the stored energy in the fuel. Petitioner quotes from a referenced document (WCAP-15604-NP, Rev. 1) that:

> "Clad[ding] oxidation can lead to significantly increased fuel rod internal pressures. ... In addition to oxidation causing increases in rod internal pressures, crud deposition has a similar effect since crud is a poor conductor of heat."

MEL 6-2: The petitioner asserts that not realistically modeling crud and/or oxide layers in emergency core cooling system (ECCS) models would already be a violation of 10CFR 50, Appendix K, because Appendix K requires these effects to be taken into consideration.

The petitioner concludes that: "It is clear that crud and/or oxide layers on cladding affect the stored energy in the fuel in two ways: 1) their external thermal resistance increases the stored energy in the fuel and 2) their external thermal resistance increases the fuel rod internal pressure and affects the fuel-cladding gap width, which, in turn affects the thermal conductance of the fuel-cladding gap and the quantity of stored energy in the fuel."

Comment 7. Submitted August 5, 2007 by Mark Edward Leyse

The commenter, who is also the petitioner, would like to add supplementary information to PRM 50-84.

In several other comments, the petitioner supplied information which he suggests lends support for the petition for rulemaking. In this comment, however, the petitioner states, "Petitioner would like to add supplementary information to PRM 50-84." The following is a summary of the supplementary information provided by the petitioner:

MEL 7-1: Petitioner states that in Three Mile Island Unit 1 (TMI-1), Cycle 10, rod 011 experienced a massive absorption of hydrogen since "hydrided material seems to have broken away from the outer portions of the cladding." Petitioner concludes from reviewing an NRC ACRS meeting transcript that "An increase in cladding hydrogen contributes to cladding embrittlement." Petitioner states that since rod 011 was degraded from substantial oxidation and hydrogen absorption, it would have been embrittled during Cycle 10. Thus, if a real-life LOCA had occurred during Cycle 10, rod 011 would have had a high probability of exceeding [the 10CRF 50.469b)(i) PCT limit of] 2,200^{O}F and a high probability of fracturing and fragmenting during the reflood period and would have lost structural integrity.

MEL 7-2: In support of the claim in PRM-50-84 that crud has never been properly factored into PCT calculations for LOCAs, Petitioner states that the Callaway Cycle 6 ECCS safety analysis modeled effects of crud deposition by assigning a penalty of only +4.0^{O}F. Petitioner states that a recent 2005/2006 paper (ML063390145) concludes that Callaway Cycle 6 ECCS evaluation would be more accurately modeled as a 59 micron (μm) thick crud layer that increases calculated fuel cladding surface temperature by 55^{O}C (100^{O}F). Petitioner concludes that a 100μm layer of crud would increase cladding surface temperature by more than 100^{O}F. Petitioner states that computer codes that address crud deposition do not seem to model morphologies of crud that have been documented to increase local cladding temperatures by over 180^{O}F or 270^{O}F or greater during PWR operation. Petitioner concludes, "Therefore, it is possible that the actual thermal resistance of the crud at Callaway Cycle 6 was greater than what these computer codes predict."

MEL 7-3: In support of the argument in PRM-50-84 that ECCS evaluations for a number of recent power uprates were non-conservative, the Petitioner provides information from an Indian Point Unit 2 power uprate ECCS evaluation calculation submitted in 2004. Petitioner concludes that the level of maximum cladding oxidation calculated by the Indian Point Unit 2 (IP2) licensee in the 2004 ECCS calculation is non-conservative since the ECCS evaluation calculation did not consider scenarios in which the cladding would be heavily crudded and oxidized. Petitioner further concludes that the 2004 power uprate ECCS calculations are noncompliant with 10 CFR 50.46(a)(1)(i), which requires that "ECCS cooling performance must be calculated...to provide assurance that the most severe postulated loss-of-coolant accidents are calculated" and that "it is highly probable that IP2 is currently operating in noncompliance with the parameters set forth in 10 CFR § 50.46(b), at an unsafe power level."

Comment 8. Submitted August 14, 2007 by Robert H. Leyse

RHL 8-1: The commenter provides a rebuttal to the comments on PRM-50-84 submitted by the Nuclear Energy Institute.

In those comments, NEI concludes, "The Industry position is that the petition for rulemaking submitted by Mr. Leyse is not needed and should not be considered for action by the Nuclear Regulatory Commission. The commenter states, "To the contrary, detailed attention by the NRC to the matters of PRM-50-84 is long overdue." The commenter additionally states that the industry proceeded with crud-related practices that have had no NRC review.

RHL 8-2: The commenter provides three publicly available articles: one on ultrasonic fuel cleaning services offered by AREVA, another on a technique used to sample crud flakes at River Bend Station, and a third article entitled "Fuel Crud Formation and Behavior" and published in Nuclear Plant Journal. The commenter concludes that there is a need to implement PRM-50-84 because crud deposits are ubiquitous and the issues are of high safety significance.

Comment 9. Submitted August 15, 2007 by Robert H. Leyse

RHL-9: The commenter referred to an NRC Press Release regarding an order issued to First Energy Nuclear Operating Company (FENROC). The order regards the prompt sharing of information which 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, Entergy, should be subject to a similar Order requiring that it provide information, such as the EPRI report, promptly.

Comment 10. Submitted August 17, 2007 by Robert H. Leyse

RHL-10: The commenter stated that the reviewers of PRM-50-84 should study a November 1, 1960, report authored by C.R. Breden, I. Charak, and R. H. Leyse, entitled "Water Chemistry and Fuel Element Scale in EBWR," that details the source and impact of thick crud at Argonne's Experimental Boiling Water Reactor in the late 1950's. The commenter further states that the last two sections of the report give the results of studies of the heat transfer characteristics of fuel-element scale and the effects of high-temperature heating on scale removal and fuel element growth.

Comment 11. Submitted August 22, 2007 by Strategic Teaming and Resource Sharing

STARS 11-1: The commenter 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.

STARS 11-2: The commenter 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.

STARS 11-3: The commenter also stated that NRC and licensee efficiency and effectiveness would be decreased by the requested regulations because significant resources would be required for (1) the NRC to promulgate the rule, (2) for licensees to generate additional information as part of the development of their ECCS evaluation models, and (3) for the NRC to evaluate the licensees' data and analysis.