PRM-50-84
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OFFICE OF SECRETARY
RULEMAKINGS AND
ADJUDICATIONS STAFF

July 27, 2007

Ms. Annette L. Vietti Cook
Secretary
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555-0001

Attention: Rulemaking and Adjudications Staff

Public Comment on PRM-50-84

Dear Ms. Vietti Cook

The need to implement PRM-50-84 is clearly illustrated by analysis of the following reference that includes discussions of *the wide spread coverage of tenacious crud* and the consequent *excessively high cladding temperatures and fuel damage*:

NRC, "River Bend Station - NRC Problem Identification and Resolution Inspection Report 0500458/2005008," 02/28/06, Report Details, located at: www.nrc.gov, Electronic Reading Room, **ADAMS** Documents, Accession Number: ML060600503.

This reference discloses that for cycle 8 at River Bend, "*General Electric (the fuel vendor) calculated that the cladding surface temperatures approached 1200 °F in localized areas.*"

This reference also discloses that during cycle 11 at River Bend, "*Rod Bowing: The licensee identified one problem that was unique to the Cycle 11 failures - significant bowing of the failed fuel pins. This was caused by high temperatures over a larger area of the fuel pins. The cladding temperature had been sufficiently high to anneal the metal, change the micro structure of the zircaloy material. The minimum temperature for annealing zircaloy is about 930 °F. The team determined that the wide spread coverage of the tenacious crud likely caused this phenomena.*"

However, even with all of its awareness of the excessively high cladding temperatures and rod bowing caused by *the wide spread coverage of tenacious crud,* the NRC reported that the issue was of very low safety significance, "*... during Operating Cycles 8 and 11, the licensee operated the core outside of the specified MCPR limits, as evidence by excessively high cladding temperatures and fuel damage. Because* ***this issue is of very low safety significance ...***"

Template = SECY-067

SECY-02

Of course, the NRC evaluators of PRM-50-84 should study ML060600503, and track the path to the determination that ***this issue is of very low safety significance***. If the NRC evaluators do that, they will find the following interesting paragraph:

"The team reviewed one technical study that discussed the behavior of crud on the surface of boiler tubes ("Two-Phase Flow and Heat Transfer," D. Butterworth and G.F. Hewitt, Oxford University Press, 1977). The team noted that the thermal resistance of crud is not normally sufficient to cause cladding temperature increases consistent with those observed during Cycle 8. In most circumstances, "wick boiling" occurs within the crud. That is, capillary coolant channels within the crud deliver coolant to the cladding surface. Steam then escapes from the cladding surface in chimney type plumes. This is a fairly effective method of heat transfer. However, in some instances the capillary coolant channels can become clogged, creating a static steam blanket on the cladding surface. Steam is an exceptionally good thermal insulator. This is the process that caused the very high cladding surface temperatures and ultimately resulted in fuel cladding failure."

Now, it is a gross exaggeration to assert that in *most circumstances, "wick boiling" occurs within the crud* of LWRs. And it is clearly erroneous to assert that in the absence of wick boiling a static steam blanket forms on the cladding surface beneath the crud. I have studied the Butterworth report, and it is a compendium of reports; Chapter 15 is a report by R. V. Macbeth, **Fouling in Boiling Water Systems.** Macbeth is a recognized expert in the field. The conditions at River Bend and other LWRs are far from the relatively pure magnetite deposits that yield effective wick boiling. Indeed, Macbeth reports, *"The risk of an excessive temperature occurs when porous magnetite becomes impregnated with compounds other than iron, and this is shown by the results for rod number 33 ICL in Fig. 15.4. In this rod the magnetite structure was extensively blocked or infilled with calcium and silicon compounds. Consequently, the wick boiling process must have been severely restricted and the transfer of heat was mainly by normal conduction."*

River Bend Station issued License Event Report, **Thermally-Induced Accelerated Corrosion of BWR Fuel,** (ML003692155) that addresses the unusually heavy deposition of crud on fuel bundles during cycle 8. The following is copied from page 4 of the LER:

"Cycle Differences

A synergy among various parameters related to plant chemistry and core operation is required, in conjunction with the iron deposits, to adequately explain the corrosion phenomenon. A review of parameters that changed in any significant way between Cycle 7 and Cycle 8 was performed.

- *The amount of iron input to the reactor vessel increased by 70% in Cycle 8, versus Cycle 7, due in part to the removal of low cross-linked resins from service in the condensate demineralizers (*SF*). This removal was done because of sulfate bleed-through associated with this particular resin type. An iron oxide crud layer on the fuel provides a means to concentrate soluble elements such as copper.*
- *The amount of copper input to the reactor vessel increased by -30% in Cycle 8 versus Cycle 7, again due to the removal of low cross-linked resins from service in the condensate demineralizers. An additional source of increasing copper is the "blinding" effect of higher iron on the demineralizers copper removal efficiency. Copper has been previously implicated as an agent of local cladding corrosion in the BWR fleet. Analysis of the crud layers indicated that copper had concentrated in the crud layer adjacent to the cladding.*
- *Zinc was injected into the feedwater system in significant quantities for the first time in Cycle 8. However, the amount of zinc injected and ultimately deposited on the fuel was unremarkable, as compared to the BWR fleet experience. There is no known corrosion or corrosive agent concentration mechanism associated with zinc injection. This is not believed to be a factor in the crud formation.*
- *The plant operated in the Maximum Extended Load Line Limit Analysis (MELLLA) domain for the first time following RF-7. While this allowed plant operation at lower overall core flows, the locations of the fuel failures were not the locations of lowest flow. The failure locations show a strong correlation to peak nodal powers (as expected for a duty-related failure mechanism such as corrosion), but do not show such a correlation to low bundle flow. The lower flows due to MELLLA would only be a minor aggravating factor for crud deposition. Bundle inspections at other BWRs with high feedwater iron concentrations and MELLLA operation do not indicate any significant increases in crud levels due to MELLLA operation."*

Now, the LER was issued on May 30, 2000, and the severe crud deposits were discovered more than one year earlier on April 20, 1999. Clearly, the LER was not written without time for substantial reflection and analysis by River Bend staff and perhaps its consultants. It is apparent that with the large copper content, the crud at River Bend was deposited without any significant duration, if any duration, of wick boiling.

Returning to Macbeth, his chapter also discusses the effect of crud deposits on frictional pressure drop. He reported that the effect of crud deposits on frictional pressure drop in single phase adiabatic water flow is surprisingly large, with a friction factor for a crudded surface more than twice that of a clean surface. He added that with boiling, the impact of crud on the friction factor becomes less as the quality increases. However, at River Bend, the crud was so thick that the impact on the friction factor was must have been substantially greater than anything Macbeth considered. The reviewers of PRM-50-84 must recognize the

implications of the change in flow distribution throughout the River Bend core as fouling progressed during cycle 8. Certainly, the flow in the very heavily fouled regions was substantially less than calculated for the MELLLA domain.

Returning next to the matter of a *steam blanket on the cladding surface,* Macbeth did not report that mechanism and I believe his statement is correct; that without wick boiling heat transfer is by normal conduction. So where did the NRC's Inspection Team get that idea? It turns out that the team also had access to an EPRI proprietary report, **BWR Fuel Deposit Sample Evaluation, River Bend Cycle 11 Crud Flakes.** I have been told, *"This was an analysis of the fuel crud performed by the Electric Power Research Institute (EPRI). The EPRI analysis evaluated a sample of crud taken directly from the River Bend Station failed fuel. This document was marked proprietary. As such, the inspectors were restricted from disclosing sensitive information contained in the analysis to the general public. Instead, the inspectors sought other available information to provide a description of fuel crud cooling characteristics. The referenced document,* ***Two-Phase Flow and Heat Transfer****, D. Butterworth and G. F. Hewitt, Oxford University Press, 1977, suited this purpose."* Of course, the NRC evaluators of PRM-50-84 must study that EPRI report and include their findings in their evaluation of PRM-50-84. Perhaps the EPRI report does not address the matter of a *steam blanket on the cladding surface,* however, the idea came from somewhere and the reviewers must address this.

This letter cites only two of the references in PRM-50-84. Crud deposits are ubiquitous among the worldwide fleet of LWRs, and the issues are of very high safety significance.

Robert H. Leyse

From: Angella Love-Blair
To: SECY
Date: Fri, Jul 27, 2007 3:13 PM
Subject: Comment Letter on PRM-50-84

Attached for docketing is a comment letter on the above noted PRM from Robert Leyse that I received via the rulemaking website on 7/27/07.

Thanks,
Angella

Mail Envelope Properties (46AA43B9.1D2 : 11 : 10288)

Subject: Comment Letter on PRM-50-84
Creation Date Fri, Jul 27, 2007 3:12 PM
From: Angella Love-Blair

Created By: ALB5@nrc.gov

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Expiration Date: None
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Concealed Subject: No
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