

September 20, 2007

Mr. Gordon Bischoff, Manager  
Owners Group Program Management Office  
Westinghouse Electric Company  
P.O. Box 355  
Pittsburgh, PA 15230-0355

SUBJECT: REQUEST FOR ADDITIONAL INFORMATION RE: PRESSURIZED WATER  
REACTOR OWNERS GROUP (PWROG) TOPICAL REPORT (TR)  
WCAP16793-NP, REVISION 0, "EVALUATION OF LONG-TERM COOLING  
CONSIDERING PARTICULATE, FIBROUS AND CHEMICAL DEBRIS IN THE  
RECIRCULATING FLUID" (TAC NO. MD5891)

Dear Mr. Gresham:

By letter dated June 4, 2007 (Agencywide Documents Access and Management System Accession No. ML071580139), the PWROG submitted for U.S. Nuclear Regulatory Commission (NRC) staff review TR WCAP-16793-NP, Revision 0, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid." Upon review of the information provided, the NRC staff has determined that additional information, in the area of chemical effects, is needed to complete the review. On September 10, 2007, Christine DiMuzio and I agreed that the NRC staff will receive your response to the enclosed Request for Additional Information (RAI) questions by October 12, 2007. The PWROG should request an extension, in writing, if it requires additional time beyond October 12, 2007, to respond to this request. If you have any questions regarding the enclosed RAI questions, please contact me at 301-415-3610.

Sincerely,  
/RA/

Tanya M. Mensah, Senior Project Manager  
Special Projects Branch  
Division of Policy and Rulemaking  
Office of Nuclear Reactor Regulation

Project No. 694

Enclosure: RAI questions

cc w/encl:  
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Regulatory Compliance and Plant Licensing  
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ADAMS Accession No. ML072530244

NRR-088

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Letter to Gordon Bischoff from Tanya M. Mensah dated: September 20, 2007

SUBJECT: REQUEST FOR ADDITIONAL INFORMATION RE: PRESSURIZED WATER  
REACTOR OWNERS GROUP TOPICAL REPORT WCAP-16793-NP,  
REVISION 0, "EVALUATION OF LONG-TERM COOLING CONSIDERING  
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REQUEST FOR ADDITIONAL INFORMATION  
BY THE OFFICE OF NUCLEAR REACTOR REGULATION  
TOPICAL REPORT (TR) WCAP-16793-NP, REVISION 0, "EVALUATION OF LONG-TERM  
COOLING CONSIDERING PARTICULATE, FIBROUS AND CHEMICAL DEBRIS IN THE  
RECIRCULATING FLUID"  
PRESSURIZED WATER REACTOR OWNERS GROUP (PWROG)  
PROJECT NO. 694

By letter dated June 4, 2007 (Agencywide Documents Access and Management System Accession No. ML071580139), the PWROG submitted for U.S. Nuclear Regulatory Commission (NRC) staff review TR WCAP-16793-NP, Revision 0, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid." Upon review of the information provided, the NRC staff has determined that additional information is needed, in the area of chemical effects, to complete the review.

To facilitate an efficient and expeditious review, the NRC staff requests responses to the following questions in order to continue the review of TR WCAP-16793-NP, Revision 0. All section, paragraph, page, table, or figure numbers in the questions below refer to items in TR WCAP-16793-NP, Revision 0, unless specified otherwise.

NRC Questions

1. General Question: There are several mathematical models used in deriving predicted solubilities, fuel surface temperatures, etc. Please provide a reference for each model used that identifies the corroborating assumptions described in TR WCAP-16793-NP, Revision 0, and discuss how these models are appropriate for this scenario.
2. Page 2-2: There is a tacit assumption here that the only mechanism for blockage is by single particles bridging across the opening. Operational experience with heat exchangers shows that debris much smaller than the diameter of a tube can build up at the tube mouth and close down the opening diameter. The deposition mechanism of this smaller debris is via adhesion. For the lower core plate inlet, adhesion may occur due to increased temperature at the surface and the presence of corrosion products which have an irregular surface.
  - A. Does the model that is being used account for surface irregularities capturing smaller debris than the span diameter? If so, please explain how. If not, please justify why this could not happen or describe how the build-up of smaller debris would affect the results.

- B. How long will it take to span the gap if debris build-up were to occur from all the particulate passing through the sump screen depositing at the core inlet area? Please explain how your answer was derived.
3. Page 2-2: The assumption related to the largest particle size passing into the reactor vessel does not account for particulate agglomeration downstream of the screens, particularly during the temperature drop in the Residual Heat Removal (RHR) heat exchangers. How does the model demonstrate that the particle size (due to agglomeration of micron and sub-micron size precipitates) and temperature decrease (causing subsequent precipitation) will not exceed what is predicted here for particle size?
4. Page 2-3: Was the partial fuel length assembly pre-conditioned so that the corrosion film on its surface would be representative of that found in a plant in its third fuel cycle? If not, describe how the presence of a representative oxide film could affect the test results.
5. Page 2-3: Was the partial length fuel assembly internally heated to the temperature anticipated when debris would come in contact with it? If not, please demonstrate what effect heat will have at the clad surface.
6. Page 2-6, Section 2.3: TR WCAP-16793-NP, Revision 0, states that fibrous debris entering the core will not tightly adhere to the surface of fuel cladding. It further states that adherence of fibrous debris is not plausible and will not adversely affect core cooling. During strainer testing, the NRC staff has observed that fiber coated with chemical precipitate can adhere to surfaces, such as plexiglass walls. Therefore, please provide a justification for why is it not plausible that fibers that have precipitate or other chemical products attached can tightly adhere to the surface of fuel cladding. If fibers did adhere to the fuel cladding, how would this affect the deposition model predictions?
7. Page 2-15: This section describes the conservative clad heat-up calculations.
- A. Is the 50 mils of solid precipitate described here in addition to the normal layer of fuel corrosion product? Please justify your answer.
  - B. Is this calculation on a clean fuel basis or a fuel surface that has the maximum allowable crud layer (~100 microns)? Please justify your answer.
  - C. Is the 'weighting' factor for the crud and the precipitate the same? Please provide a reference for the assumptions made regarding the individual contributions to this term.
8. Page 5-3: One of the stated assumptions in this section is, "The non-boiling rate of deposit build-up is proportional to heat flux and is 1/80th of the rate of boiling deposition at the same heat flux." Please provide the technical basis for this assumption. Also provide a copy of reference E-13.

9. Page 5-3: The relationship between the TR WCAP-16530-NP<sup>1</sup> dissolution model and TR WCAP-16793 deposition model is discussed in Section 5.4.1. Please clarify how the output from the dissolution model is related to the input for the deposition model. In other words, is the mass from the dissolution model equal to the mass input to the deposition model, or is the dissolution mass output reduced by precipitate settling, sump strainer debris bed filtering, etc? If the latter, please justify the credit taken.
10. Page 5-9: In Figure 5-3, please show what the fuel cladding temperature profile would look like for a case with no debris contamination at the fuel surface.
11. Page 5-9: Model predictions generally have a confidence level associated with the "calculated" value. Figure 5-3 identifies a "maximum" scale thickness. How is this maximum value calculated and does it represent a fifty percent, ninety-five percent, or some other confidence level?
12. Page C-6: Please explain the basis for the assumption that the top third of the fuel rod would be covered in debris and not the bottom third. Also demonstrate how this assumption would provide a conservative estimate for (low) heat transfer.
13. Page C-6: For modeling purposes it has been assumed that the debris that reaches the fuel rod is evenly distributed over the entire surface. The more likely scenario is that deposits will build up on one spot and continue to grow in the vicinity of the original deposition.
- A. Can the modeling be modified to have a non-uniform deposit of debris on the fuel? For example, the curves in Figure C-1 are generated for uniform deposition of debris.
  - B. What effect would localized debris build up have on the clad peak temperature? Specifically, how much debris would be necessary to exceed clad temperature limits or reduce effective cooling to the fuel assembly due to corrosion product blockage?
  - C. Please demonstrate that the uniform distribution assumption will not lead to non-conservative heat transfer conclusions.
14. Page C-6: Please show why insulation does not become incorporated into the debris covering the fuel rods. If the debris is insulation based, what would be a realistic heat transfer coefficient for this material? Please provide a reference or technical basis for this value.
15. Page C-7: Regarding Table C-7, please identify the change in solubility of sodium aluminosilicate, aluminum hydroxide, and calcium silicate at these temperatures. These compounds and other zeolites that may form have retrograde solubility. What is the rate of build up of these compounds on the fuel clad surface? Please provide a basis for your answer.

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<sup>1</sup> By letter dated March 27, 2006 (ML060890501), the PWROG submitted WCAP-16530-NP, "Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191," to the Nuclear Regulatory Commission for a formal review.

16. Page D-2: Deposition of the thickest crud layers on fuel surfaces occurs on the top third of the fuel assemblies. Therefore it seems likely that the heat conduction in the axial direction downward could be significant since there would be decreased cooling water flow.

- A. Describe how axial heat conduction would affect the temperature profile calculated assuming radial heat conduction only. Which case provides a conservative bound?
- B. Please demonstrate that the assumption made here represents the most conservative case for build up of precipitates in all interstitial sections of the fuel assembly including the top third.

17. Page D-4: Please describe what the term "contact resistance" between material layers means and why it represents a conservative assumption for these calculations.

18. Page D-6: The calculations presented here represent the instantaneous clad surface temperature maxima at 20 minutes into the accident. Although the Fuel Centerline Temperature (FCT) and Clad Surface temperatures will decrease with time after this point, the precipitate masses and thicknesses will continue to increase. Please demonstrate:

- A. What the buildup of precipitate thickness will be over the next 30 days.
- B. How the build up of the precipitates over 30 days affects the fuel clad surface temperature during this time.

19. Page E-3: Can it be shown that precipitate deposition on the RHR heat exchanger surfaces will not lead to reduced flow and heat transfer such that the maximum fuel clad temperature assumption of 800 °F will not be exceeded? TR WCAP-16793-NP, Revision 0, indicates that all debris and precipitate is transferred to the vessel. Please demonstrate that a drop in the heat exchanger flow is not a more conservative assumption based on reduced heat exchanger cooling capability.

20. Page E-3, "Discussion of Major Assumptions":

- A. Do any of these assumptions account for an increase of deposit mass based on the incorporation of boric acid into the deposited material? Please justify your answer.
- B. Do these calculations include 10 percent by weight of the boric acid in the precipitate? Please justify your answer.
- C. Are waters of hydration included in these calculations? If not, please describe the effects of including waters of hydration?

21. Page E-7: Should there be parentheses around the term  $(m_x/m_T)$ ?

22. Page E-7: Should there be parentheses around the terms  $(C_x \cdot \text{Flowrate} \cdot dt)$ ?

23. Page E-7: Does the value for  $h_{fg}$  only consider the enthalpy of dissolved boric acid or does it include all other dissolved species as well? Please justify your answer.
24. Page F-3: Please demonstrate how the calculations performed here provide the appropriate values for solubility. Specifically:
- A. The value of 0.69 parts per million (ppm) is unrealistic for lithium concentration - what happens when this is reduced to 0.2 or less?
  - B. Please calculate the solubilities when aluminum is 100 ppm at fuel temperature of 260 °F.
  - C. Please calculate the solubilities when the expected concentrations of hydrogen and oxygen that result from radiolysis exist.
25. Page E-11, Section E.7: This section describes thermodynamic predictions for chemical compounds that would deposit on the fuel. Results are included from Westinghouse Electric Company (Westinghouse) thermodynamic predictions and from thermodynamic equilibrium code calculations performed by AREVA NP, Inc:(AREVA). The NRC staff has a number of questions related to these thermodynamic predictions:
- A. What is the basis for the Westinghouse thermodynamic predictions?
  - B. How are the AREVA and Westinghouse predictions integrated to model the quantity and compounds that form in the vessel? If only one is used, please indicate why it is more conservative than the other.
  - C. Does the model account for the change of  $\text{Ca}(\text{BO}_3)_2$  to  $\text{CaB}_2\text{O}_5$  when the precipitate is in contact with the fuel surface above 180 °F? Please justify your answer.
26. Page E-14: Reference E-18 refers to the scale build-up and thermal conductivity in a desalination unit. Please provide the reference and show how the thermal conductivity of scale and insulation on the fuel would be comparable to that in the desalination unit.
27. Page F-2: The OLI StreamAnalyzer™ thermodynamic code data bank most probably does not include data from concentrated borated water environments. Therefore, please justify why the thermodynamic equilibrium code predictions are reliable for use when modeling a concentrated boron environment in the reactor vessel following a postulated loss-of- coolant- accident (LOCA).
28. Page F-3: Table F-1 provides an input summary for solubility calculations that are intended to be reasonably representative of the expected post-LOCA conditions and not bounding of all plants and scenarios. Was a parametric study performed to evaluate conditions other than the four results summarized in Table F-1? For example, were sensitivity studies performed to assess effects of pH, temperature, and elemental concentrations?



29. Page F-4: Thermodynamic software results from Run 1 are presented in Section F.5.1. Based on the OLI software, approximately 100 percent of the aluminum and 77 percent of the silicon in the sump are predicted to form a sodium aluminum silicate precipitate. No additional precipitation is predicted as the sump liquid is heated to core temperatures. Please compare the in-vessel deposition results based on this assumption to the results that would be predicted given the same concentrations but assuming no sodium aluminum precipitate formed in the sump.

30. Page F-5, Section F.5.3: There appears to be an assumption here that any silica specie in the Reactor Coolant System will be present at the starting point as  $\text{SiO}_2$ . The predominant form of silica in the RCS (refueling water storage tank and the spent fuel pool) is reactive silica and not  $\text{SiO}_2$ .

- A. Does the model assume that  $\text{SiO}_2$  precipitates without starting out as  $\text{H}_2\text{SiO}_4^{2-}$ ?
- B. How does the presence of silica as  $\text{H}_2\text{SiO}_4^{2-}$  or as  $\text{H}_3\text{SiO}_4^{1-}$  affect the potential precipitation of other species such as calcium silicate or sodium aluminum silicate?
- C. Even if  $\text{SiO}_2$  were to precipitate it would likely be transformed into  $\text{H}_2\text{SiO}_4^{2-}$  rather rapidly. How does this change the predictions of the model?