February 12, 2010

Mr. Anthony Nowinowski, 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) POLESTAR APPLIED TECHNOLOGY, INCORPORATED 4025CF.QA.04, REVISION 1, "STARFIRE MODEL REPORT" (TAC NO. MD9428)

Dear Mr. Nowinowski:

By letter dated June 27, 2008 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML082380314), the Pressurized Water Reactor Owners Group (PWROG) submitted a topical report (TR) PSAT4025CF.QA.04, Revision 1, "StarFIRE Model Report," on behalf of Polestar Applied Technology, Incorporated (PSAT), for U.S. Nuclear Regulatory Commission (NRC) staff review. Upon review of the information provided, the NRC staff has determined that additional information is needed to complete the review. On February 4, 2010, Mr. Chad Holderbaum, PWROG project manager, and I agreed that the NRC staff will receive your response to the enclosed Request for Additional Information (RAI) questions within 30 days of the date of this letter. If you have any questions regarding the enclosed RAI questions, please contact me at 301-415-4053.

Sincerely,

/RA/

Jonathan Rowley, Project Manager
Special Projects Branch
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Project No. 694

Enclosure: RAI questions

cc w/encl: See next page

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REQUEST FOR ADDITIONAL INFORMATION

BY THE OFFICE OF NUCLEAR REACTOR REGULATION

PSAT 4025CF.QA.04, REVISION 1, "STARFIRE MODEL REPORT"

PRESSURIZED WATER REACTOR OWNERS GROUP (PWROG)

PROJECT NO. 694

The StarFIRE model is intended to predict the release of radioactive iodine from leaks in emergency safety feature systems following design basis accidents. In its review of the technical bases of this model, the Nuclear Regulatory Commission (NRC) staff has identified areas of concern that may be addressed by responses to the requests for additional information presented below:

1. Under some conditions, the applicant hypothesized that water leaking from the emergency safety feature will "flash" boil. The steam production will disrupt the remaining leaked liquid and produce droplets. The applicant asserts that the droplets produced by the disruption will be large – similar to droplets produced by spray systems. Therefore, the droplets are assumed to drop rapidly to the floor without evaporating. Considering that measurements of flash boiling liquid streams indicate drop sizes of more than an order of magnitude smaller than those hypothesized [Blachandar et al., 1998], the staff does not have reasonable assurance that the treatment of droplets is conservative.

   Please provide additional information to justify the neglect of droplet transport outside the cell and evaporation.

2. The StarFIRE model assumes that only molecular iodine vaporization from water needs to be considered. The model neglects formation and vaporization of volatile organic iodides such as methyl iodide, CH_3I, which is known to occur [Beahm et al., 1992]. These organic iodides will have a greater potential for partitioning from the aqueous phase into the gas phase than molecular iodine.

   a. Please provide additional information to justify the neglect of organic iodide formation considering contamination of the water sources available to the emergency safety systems from accident events and the continuing radiolysis and pyrolysis of organic materials within the containment such as cable insulation.

   b. Other potentially volatile species have been detected by mass spectrometry in "flashing" aqueous solutions such as hypoiodous acid, iodine, and iodous acid [Láňová & Vřeštál, 2002]. Please provide additional information to justify the neglect of these species and their vaporization from aqueous solution in the StarFIRE model.

3. The model parameterization for solution concentrations of molecular iodine apply to conditions near room temperature. However, more recent studies have determined the rate constant for the reaction of iodide with hydrogen peroxide to be temperature

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dependent [Burns & Marsh, 1986]. At the temperatures of interest, the rate constant would be about two orders of magnitude larger than that implied by the parameters adopted in the StarFIRE model. This larger rate constant can produce a correspondingly large increase in the concentration of aqueous molecular iodine.

Please provide additional information to justify the parameters adopted for the model in StarFIRE.

4. The mass transport model of the iodine release from the water pool accumulating below the leak in the emergency safety feature system neglects the effects of evaporation. However, it would be expected that evaporation would enhance the mass transport of iodine across the boundary layer and into the cell volume.

   Please provide additional information to justify the neglect of enhanced mass transport of molecular iodine by evaporation of water from the surface of the pool.

5. The mass transport model is based on assuming mass transport from a flat plate. The liquid surface modeled as a solid flat plate is a simplification that is not properly justified as being conservative. It has been shown that capillary waves and even gravity waves can form on the surface depending on the magnitude of convective flow across the surface [Wu, 1968], and that these waves will affect the gas phase mass transport in known ways [Mackay & Yeun, 1983].

   Please provide additional information to justify the selection of a solid flat plate as the basis of mass transport modeling.

6. In the model, molecular iodine released to the gas phase will not react while suspended in the atmosphere. It is known, however, that thermal and radiolytic processes will cause gaseous iodine to oxidize to form very fine iodine oxide particles [Saiz-Lopez, et al., 2006]. Formation of such particles could reduce the back-pressure that retards mass transport of molecular iodine from the water pool to the gas phase but would not reduce the amount of iodine available for release from the cell.

   Please provide additional information to justify the neglect of gas phase reactions of molecular iodine to form fine aerosol particles.

7. The model of the iodine concentration in solution is based on a quasi-steady state reaction of iodide and hypoiodous acid with hydrogen peroxide. A second product of the reactions is oxygen gas. Since the water pool will be saturated with oxygen from the ambient atmosphere, oxygen produced by the reaction of hydrogen peroxide with iodide will nucleate bubbles in the liquid. The rupture of these bubbles at the water surface would be expected to throw off contaminated liquid as droplets of aerosol dimensions [Tomaides & Whitby, 1976; Garner, et al., 1954]. These fine droplets could be transported from the cell and could evaporate to form even finer and more easily transported particles of radioactive contaminants from the water. Therefore, the staff does not have reasonable assurance that neglecting the formation of these droplets is conservative.

Please provide additional information to justify not including this radionuclide release mechanism in the StarFIRE model.

8. The model assumes that partitioning of iodine from the liquid phase to the gas phase during the flashing process can be neglected based on a thermodynamic analysis [Hobbins, 2006]. This analysis considered iodine to be present in the solution only as dissolved cesium iodide. The analysis neglected speciation of dissolved iodide ion to molecular species such as molecular iodine, atomic iodine and hypoiodous acid as a result of radiolytic processes or the reaction of oxygen dissolved in the water within the pressurized containment [Paquette, 1989]. Therefore, the staff does not have reasonable assurance that the neglect of molecular species such as molecular iodine, atomic iodine and hypoiodous acid is conservative.

   Please provide additional information to justify not including these molecular species in the analysis of iodine partitioning into the gas phase during flashing.

9. There are arguments against dryout of deposited droplets based on the hygroscopicity of cesium hydroxide. Considering the extensive contamination of water sources for the emergency safety feature system, cesium is likely to be in the evaporating solution in a less hygroscopic chemical form than cesium hydroxide, such as cesium molybdate, cesium borate, or cesium silicate [Johns, et al., 2005].

   Please provide additional information to justify not including droplet dryout, considering the possible formation of alternative species.

10. In the StarFIRE report, it states that the users will apply the minimum pH from the 30-day pH calculation. In some cases, the minimum pH would be before buffer is added to the sump. Then the pH value would be approximately 4. Is this pH value accounted for, and are there any assumptions made in the initial time before buffer is added?

11. Please provide qualification of the random number generator and Monte Carlo methods.

12. In the model, the walls and floors of the room are coated with epoxy. Considering that there are many different types of coatings that could be used to coat the floor and walls, is it conservative to assume the walls and floors will be coated with epoxy?

13. In the report, it is assumed that the pool being well-mixed is a conservative assumption. However, it is well known that iodine tends to accumulate at surfaces [Ghosal, et al., 2005]. Therefore, being well mixed appears to be more a realistic assumption than a conservative assumption.

    Please provide additional information to justify the well mixing assumption as conservative.

14. In the report, it is assumed that the gas phase above the water pool will be well-mixed and at a uniform concentration. This does not appear to be a conservative assumption, since it would be more conservative to assume that vaporized material leaks directly to an opening of the cell.

Please provide additional information to justify the well-mixing assumption as conservative.

15. In the model, mass transport in controlled by binary diffusion across a boundary layer. However, this does not appear to be justified. The liquid pool is evaporating and the flux of water vapor from the liquid pool across the boundary layer will enhance transport of molecular iodine across the boundary layer. Therefore, a ternary diffusion situation should not be treated as a simple binary problem.

    Please provide additional information to justify the applicability of the use of binary diffusion.

16. The NRC staff finds that the argument provided in Section 2.8 of the StarFIRE model report does not provide sufficient detail to support the conclusion that the iodine release to the environment from backleakage to the reactor water storage tank (RWST) is negligible. The NRC staff has found that the assumptions used in Section 2.8 are not justified based on comparisons with specific plant analyses. For instance, Section 2.8 makes the assertion that engineered safety features (ESF) backleakage to the RWST is on the order of 10 gallons per hour. The NRC staff has reviewed licensee calculations using backleakage rates as high as 1200 gallons per hour. In addition, the NRC staff has approved licensee evaluations where the dose contribution from RWST backleakage is greater than the dose from normal ESF leakage.

    Please provide additional information to support the conclusion that “the iodine release to the environment from the RWST is expected to be several orders of magnitudes smaller than that from the ESF leakage pool, and is therefore negligible.” Please include detailed dose consequence evaluations based on actual plant parameters for several different sites covering a range of variables affecting the analysis.

REFERENCES

E.C. Beahm, C.F. Weber, T.S. Kress, and G.W. Parker, “Iodine Chemical Forms in LWR Severe Accidents”, NUREG/CR-5732, April 1992.

R. Blachandar, S.R. Mulpuru, and M.H. Ungurain, “A Note on Particle Size Measurements in Two-phase Flows,” Transactions of the ASME, *120* (1998) 390-397.

W.G. Burns and W.R. Marsh, “The Thermal and Radiolytic Oxidation of Aqueous I^- and the Hydrolysis and Disproportionation of Aqueous I_2,” AERE-R-10767, Harwell Laboratory, Oxfordshire, UK, March 1986.

F.H. Garner, S.R.M. Ellis, and J.A. Lacey, Transactions of the Institute of Chemical Engineers, *32* (1954) 222.

R.R. Hobbins, “Iodine Behavior in a Flashing Liquid, A Thermodynamic Assessment,” October 19, 2009

R.C. Johns, B.C. Letellier, K.J. Howe, and A.K. Ghosh, “Small-scale Experiments: Effects of Chemical Reactions on Debris-bed Head Loss – A Subtask of GSI-191,” NUREG/CR-6868, March 2005.

B. Láňová and J. Vřeštál, “Study of the Bray-Liebhafsky Reaction by On-line Mass Spectrometry,” The Journal of Physical Chemistry, *106A* (2002) 1228-1232.

J. Lin, “StarFIRE Model Report”, PSAT 4025CF.QA 04, Rev. 1, Polestar, December 14, 2007.

D. Mackay and A.T.K. Yeun, “Mass transfer coefficient correlations for volatilization of organic solutes from water,” Environmental Science and Technology, *17* (1983) 211-217.

J. Paquette, “Modeling the Chemistry of Iodine”, Proc. 2nd CSNI Workshop on Iodine Chemistry in Reactor Safety, A.C. Vikis, editor, AECL-9923. CSNI-149, Atomic Energy of Canada, Ltd., March 1989.

A. Saiz-Lopez, et al., “Modelling molecular iodine emissions in a coastal marine environment: The link to new particle formation“, Atmospheric Chemistry and Physics, *6* (2006) 883.

M. Tomaides and K.T. Whitby, “Generation of Aerosols by Bursting of Single Bubbles,” Fine Particles, B.H.Y. Liu, editor, Academic Press, 1976.

J. Wu, “Laboratory Studies of Wind-wave Interactions,” The Journal of Fluid Mechanics, *34* (1968) 91.

S. Ghosal, J.C. Hemminger, H. Bluhm, B.S. Mun, E.L.D. Hebenstreit, G. Ketteler, D.F. Ogletree, R.G. Requejo, and M. Salmeron, “Electron Spectroscopy of Aqueous Solution Interfaces Reveals Surface Enhancement of Halides,” Science, *307* (2005) 563-566.