Project No. 694

March 18, 2010

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Washington, DC 20555-0001

Subject: Pressurized Water Reactor Owners Group -
Responses to NRC Request for Additional Information Regarding the Review of
the Whorley Parsons Polestar StarFIRE Model " (PA-ASC-0302)

Reference: 1. Letter, D. Buschbaum to USNRC Public Document Room, "Submittal of
PSAT4025CF.QA.04, Rev 1, StarFIRE Model Report (Proprietary) OG-08-165,
May 6, 2008

2. Letter, D. Buschbaum to USNRC Public Document Room, "Re-submittal of
PSAT4025CF.QA.04, Rev. 1, StarFIRE Model Report (Proprietary), OG-08-223,
June 27, 2008

3. Request for additional Information:Pressurized Water Reactor Owners Group
(PWROG) Topical Report (TR) Polestar Applied Technology, Incorporated
4025CF.QA.04, Revision 1, "StarFIRE Model Report" (TAC No. MD9428)

The Pressurized Water Owners Group submitted the subject StarFIRE model for review and
approval in reference 1 and 2.

Attached to this letter are the industry responses to the referenced official RAIs. These RAI
responses are being provided to document the requested additional information in support of the
staff review of the StarFIRE model leading to the eventual issuance of a draft Safety Evaluation.

We appreciate the opportunity to work with the Staff during the review of this model for
calculating iodine re-evolution from Engineered Safety Feature (ESF) leakage pools.

DO 48

NRR

If there are any questions on our responses please feel free to contact me at 704-382-8619 or Mr. Robert Schomaker at 434-832-2917.

Very truly yours,

R. J. Schomaker approving for M. Arey

Melvin L. Arey, Chairman
PWR Owners Group

MLA:RJS:rfn

Enclosure: RAI Responses

cc: PWROG Management Committee Participants in PA-ASC-0302
        PWROG Analysis Subcommittee Participants in PA-ASC-0302
        PWROG PMO
        J. Rowley, USNRC
        S. Rosenberg, USNRC
        R. Schomaker, AREVA NP

Response to NRC Request for Additional Information on StarFIRE Model Report

March 8, 2010

This note contains responses to NRC Request for Additional Information (RAI) contained in a November 19, 2009 NRC memorandum from A. Boatright to S. Rosenburg addressing the PWR Owners Group submittal of the WorleyParsons Polestar StarFIRE model for calculating iodine re-evolution from engineered safety feature (ESF) leakage pools.

For each RAI, the RAI itself is repeated followed by the response. The references cited in the RAIs themselves are denoted in the same manner as was done in the RAI (i.e, author name and date), but are not listed in here. The references cited in the RAI responses are denoted by consecutive number (e.g., [1], [2], [3], etc.) and are listed at the end of the responses.

RAI 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.

Response to RAI 1

The reference [Blachandar et al., 1998] is not applicable to the StarFIRE model since the experimental condition in the reference (i.e., saturated water at 40 bars and 235 °C) is so much higher than what is likely for ESF systems in PWR accidents (typically sub-cooled water at 10 bars and ~130 °C for a few hours and then becoming much cooler for the remaining portion of the accident). This may be seen further as follows.

During the course of the accident, ESF leakage iodine re-evolution outside containment is only possible after the low pressure ECCS pumps begin to work in the recirculation mode. So, the ESF leakage temperature is, at upper limit, the containment sump water temperature (which typically reaches a peak of about 130 °C early on and declines to below 100 °C in a few hours and continues to decline monotonically). The pressure, on the other hand, is the discharge pressure of the low pressure pumps (about 150 psi or 10 bars).

Under these conditions, the flashing fraction is about 5% initially, declining as temperature declines. In contrast, the flashing fraction under the experimental conditions in the reference will reach more than 26%. Thus, we conclude that the reference is not applicable.

Given the fact that the ESF leakage is caused by the same pumping system as used for the containment spray, it is reasonable to assume that the leakage droplet size is similar to the containment spray droplet size, if not larger. Based on the reference [1] information on spray droplet size analysis, one can conclude that volume (or mass) mean droplet size of a containment spray system is much bigger than 500 μm (more like 1250 μm as shown in Figure 7 on Page 13 of reference [1]).

Finally, the argument that the evaporation of droplets to dryness will not occur is in line with the existing Standard Review Plan position which assumes only 10% flashing evaporation from the droplets.

RAI 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, CH3I, 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 HOI, I, and HIO2 [Láňová & Vřeštál, 2002]. Please provide additional information to justify the neglect of these species and their vaporization from aqueous solution in the StarFIRE model.

Response to RAI 2a

There are a number of organic substances in containment that will contribute to the formation of organic compounds in the aqueous phase, with painted surfaces likely to be the greatest contributor. As discussed in an excellent review paper [2], while these organic compounds can react with iodine in the aqueous phase to form iodides, most of these organic iodides are large molecules with large partition coefficients in contrast to methyl iodide, CH_3I, which has a relatively small partition coefficient. The net effect is that the contribution of organic iodides to volatile iodine in the gas phase is neglibible relative to I_2.

Response to RAI 2b

Species such as HOI, I, and HIO_2 are intermediate species in chemical reactions oxidizing I⁻ to I_2 and reducing I_2 to I⁻. In experiments designed to measure the generation of volatile iodine from water containing iodide and subject to a radiation field, no mention is made of the measurement of these species in the gas phase [2, 3, 4]. It should be pointed out that the partition coefficient of HOI is very high, > $1x10^4$ [2]. I_2 is the dominant chemical form of iodine volatilized from the aqueous phase [2] and intermediate species such as HOI, I, and HIO_2 can be neglected.

<u>RAI 3</u>

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 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.
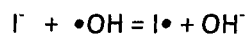
Please provide additional information to justify the parameters adopted for the model in StarFIRE.
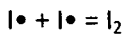
<u>Response to RAI 3</u>

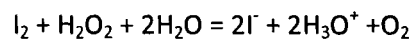According to reference [2], the reaction

$$2H^+ + 2I^- + H_2O_2 = I_2 + 2H_2O$$
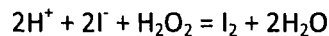
is much less important than the reaction with the radical, •OH,

$$I^- + •OH = I• + OH^-$$

followed by

$$I• + I• = I_2$$

While the rate of oxidation of I^- by H_2O_2 increases with temperature, the rate of reduction of I_2 by H_2O_2,

$$I_2 + H_2O_2 + 2H_2O = 2I^- + 2H_3O^+ + O_2$$

also increases with temperature, leading to a reduction in the rate of production of I_2 in the aqueous phase with increasing temperature [5]. This finding is in agreement with that reported by reference [6], attributed to Burns in reference [7], i.e., the conversion of I^- to I_2 in aqueous solution was measured as 45% at 30°C and 10% at 70°C.

<u>RAI 4</u>

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.

<u>Response to RAI 4</u>

Work is still ongoing to assess the effect of water evaporation from the ESF leakage pool on the transport of gaseous iodine across the boundary layer over the pool surface.

The response to RIA 4 will be complete by April 5, 2010.

RAI 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.

RAI 5 Response

The air velocity in the ESF leakage pool compartment is expected to be less than 1 m/s, considerably lower than the velocities considered in the wind-induced wave experiments, i.e., 3.3 to 13.7 m/s in reference [Wu, 1968] or 6 to 13 m/s in reference [Mackay & Yeun, 1983]. A survey of a variety of ventilated, indoor workspaces by Russian researchers [8] shows that the wind speed is typically about 0.3 – 0.4 m/s with a peak at 1 m/s. For these reasons, the wave effect on heat and mass transfer is expected to be much smaller than that noted in the NRC references and is not expected to significantly impact the mass transfer coefficient used in the StarFIRE model.

In the Monte Carlo calculation accompanying the StarFIRE model report, we made a very conservative assumption with regard to the air flow velocity (which tends to minimize the boundary layer DF) by assuming the upper limit of the air flow as high as 7.8 m/s. In reality, given that the supply and exhaust ductwork is generally located high in the ESF cells, well away from the surface of any ESF leakage pool, high air flow velocities directly over the pool surface are very unlikely.

A final point is that since mass transfer and heat transfer go hand-in-hand, if the wave effect enhances the mass transfer, it will also enhance the heat transfer, which in turn decreases the partitioning of aqueous iodine into gaseous iodine.

RAI 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.

RAI 6 Response

The formation of iodine oxide aerosol particles would have been included in the experimental measurements of iodine above irradiated iodide solutions, such as those reported in references [2, 3, 4, 5]. However, the aerosols described by [Saiz-Lopez, et al. 2006] are very dilute, so if they were generated in experiments that evolved I_2 in the gas above irradiated iodide solutions, they would not be significant. The aerosols of [Saiz-Lopez, et al. 2006] are described as 1x 10^5 particles/cm^3 maximum, with a particle density of 4 g/cm^3 and a maximum particle size of 10 nm. From this information, one can calculate a maximum aerosol density of 2.1x10^{-13} g/cm^3. In experiments in which I_2 is evolved into the gas space above an irradiated solution of iodide, a typical iodine concentration measured is 1x10^{-9} mol/L, which translates into 1.4x10^{-10} g/cm^3. The maximum [Saiz-Lopez, et al. 2006] aerosol mass density is three orders of magnitude less that of the gaseous I_2 measured in iodide radiolysis experiments. Thus, the formation of iodine oxide aerosols can be neglected.

RAI 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.

RAI 7 Response

Oxygen is not produced by the oxidation of I^- to I_2 by H_2O_2, but it is produced by the reduction of I_2 by H_2O_2 (see RAI 3 Response above). When the pH is controlled at 7 or above, the concentration of I_2 in the aqueous phase will be quite small, so its reduction by H_2O_2 would produce only a very small amount of O_2. The [Tomaides and Whitby] and [Garner, et al.] references were reviewed. Experimental data and equations from [Tomaides and Whitby] were used to estimate the mass of iodide entrained in liquid aerosols generated by the bursting of oxygen bubbles at the surface of the water pool. The estimate assumed an oxygen concentration in the pool equal to the concentration of I_2 in the aqueous phase (clearly conservative) at a pH of 7.0, an iodide concentration of 1 x 10^{-4}, and a temperature of 100°C. The result is an iodide concentration in the gas phase 4 orders of magnitude less than that of I_2. The

effect of oxygen bubbles bursting to generate liquid aerosols containing iodide would have been included in experimental measurements of iodine above irradiated iodide solutions, such as those reported in references [2,3,4,5]. However the effect is too small to have been observed and can be neglected.

RAI 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 CsI. 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.

RAI 8 Response

The evolution of iodine vapor species from a flashing pool can be evaluated by application of the partition coefficient for the appropriate species. According to reference [2], the only species of significance is I_2.

RAI 9

There are arguments against dryout of deposited droplets based on the hygroscopicity of CsOH. 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.

Response to RAI 9

Cesium being less hygroscopic does not significantly impact the case for not including droplet dryout since hygroscopicity is not the fundamental condition for the argument of no evaporation of droplets to dryness. The fundamental condition is the fact that there is no energy from the surrounding air to cause the droplet to evaporate to dryness since the droplet temperature is significantly higher than its surrounding.

Note that the other cesium species suggested in the RAI (i.e., cesium molybdate, cesium borate, or cesium silicate), while not as hygroscopic as CsOH, are still somewhat hygroscopic which will make it harder for droplets to evaporate.

Finally, the argument that the evaporation of droplets to dryness will not occur in this problem is in line with the existing Standard Review Plan position which assumes only 10% flashing evaporation from the droplets.

RAI 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?

Response to RAI 10

The intent in applying the StarFIRE model is to apply the minimum buffered pH. The impact of any lower pH period prior to buffer addition, should one exist, is not considered significant for the following reasons:

- ESF leakage is a matter of concern beginning with the transfer to cold leg recirculation since it is at this time that contaminated containment sump liquid is recirculated outside containment where it becomes part of the ESF leakage pathway for release of fission products to the environment following a LOCA. Generally, the buffer/caustic addition systems in PWRs will have begun operation before the onset of recirculation (for example, Containment Spray System caustic or buffer additive subsystems, baskets of buffering agents such as tri-sodium phosphate in the containment sump, buffering agents such as sodium tetraborate in ice condensers of ice condenser plants). Accordingly, the interval between the onset of recirculation and the containment sump pH reaching and exceeding 7 is relatively short, expected to be on the order of minutes.
- As noted above, ESF leakage is a matter of concern beginning at the time of onset of recirculation, and in general the addition of caustic or buffering agents will have begun before this time. Thus the pH of the solution in the containment sump at the time of onset of recirculation will be higher than 4 (in the range to 5 or 6 or higher).
- The timing of core damage associated with the method of AST is relatively fast under the assumptions of a large break and complete failure of the ECCS for two hours. If an accident were to occur it is more likely that core damage and associated fission product releases would occur over a longer time period (e.g., smaller break, at least some coolant injection such as charging pumps that delays or limits core damage). This will further mitigate the effect of an interval of low containment sump pH.

A final point is that the AST includes in-vessel release of a significant fraction of the core inventory of cesium (0.3 for PWRs), traditionally assumed to be in the form of CsOH [9, 10]. This amount of CsOH typically results in a concentration of [OH⁻] in the range of 1E-4 to 3E-4 mol/L in the containment sump. Depending upon the rate of strong acid addition from radiolysis of water and of chloride-bearing materials (mainly cable insulation) it would require of the order of many hours (as long as 24 hours for some plants) to neutralize this [OH⁻]. It is now recognized that cesium will take other forms in the post-

accident environment. For example, the significant amount of boric acid expected in the aqueous phase in a PWR containment makes $CsBO_2$ a likely form of cesium. Here again, it would require at least several hours to reach a pH of 7 in the presence of the borate buffer from $CsBO_2$.

In any event, if a period of pH < 7 occurs at all, is very likely to be short and not impact the total ESF leakage iodine release.

RAI 11

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

RAI 11 Response

The Monte Carlo simulation was performed in an Excel spreadsheet using the XLSim® (an Excel Add-in) from AnalyCorp (http://www.analycorp.com/). AnalyCorp is founded by Dr. Sam Savage, a consulting professor at Management Science and Engineering Department, Stanford.

RAI 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?

RAI 12 Response

The coating characteristics are a user input in the StarFIRE model. The epoxy is only used as an example input in StarFIRE.

RAI 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.

RAI 13 Response

There are several reasons why the accumulation of iodine at surfaces is not considered a significant effect with respect to the re-evolution of I_2 from ESF pool leakage. The most important of these is the fact that this surface accumulation effect would have been included in the experimental measurements of iodine above irradiated iodide solutions which are the basis for the StarFIRE model [2, 3, 4, 5, 6]. A second reason is the fact that the surface accumulation effect applies to the ionic form (I^-). The distribution of aqueous I_2 will be unaffected by this phenomenon, as it is an electrically neutral species.

With regard to the StarFIRE assumption of well-mixed being conservative, what was meant is that when molecules of aqueous I_2 are transported from the surface to the gas phase, it is assumed that aqueous

bulk I_2 immediately fills the vacancies created by this transport (i.e., instantaneous restoration of equilibrium conditions). This is conservative since in reality it will take time for aqueous I_2 to diffuse from the bulk to the surface.

A final point is that the experiments of [Ghosal, et al. 2005] cited in RAI 13 were with saturated salt solutions and, therefore, at much higher concentrations than would be encountered in water pools in post-accident reactor containments, which are in the range 1×10^{-4} to 1×10^{-6} mol/L of iodide. There has been recent work on dilute salt solutions in the millimole concentration range [11, 12] measuring iodide and other anion concentrations at the surface of the solution. Included in these results are models for calculating the excess anion concentrations at the surface, using parameters that fit experimental data. Calculations with these models indicate an enhanced concentration of iodide ions on the order of 3x that of the bulk concentration at solution concentrations of interest for reactor accident analyses. It should be noted that the distance over which the excess surface concentration exists is very narrow, on the order of 10 Angstroms, or 1×10^{-7} cm, so only a tiny fraction of the iodide ions in the solution are involved. For example, in a shallow pool of 1 cm depth, the fraction of the pool volume affected is 1E-7.

RAI 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.

Response to RAI 14

The "opening in the cell" that is the leak path for iodine re-evolved from an ESF leakage pool is the supply and exhaust ductwork of the safety-related ventilation system that cools and conditions the air in the cell. Safety-related ventilation systems in cells housing ESF equipment that could leak contaminated coolant are designed to provide a well-mixed, well-ventilated space in the cell, and the supply and exhaust ductwork is generally located high in the cell away from the surface of any ESF leakage pool. It is unrealistic that the iodine evolving from a leaked pool surface could somehow disperse in a narrow plume directly to the ducts of such a ventilation system.

RAI 15

In the model, mass transport is 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.

RAI 15 Response

RAI 15 is the same as RAI 4 and the RAI 4 response applies.

RAI 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 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 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.

Response to RAI 16

The StarFIRE model will be limited to ESF leakage pools. RWST backleakage will be addressed separately by the licensee.

References

1. D.A.Powers et al, "A Simplified Model of Aerosol Removal by Containment Sprays," NUREG/CR-5966, June, 1993.
2. J. C. Wren, et al., "The Chemistry of Iodine in Containment," Nucl. Technol. **129**, 297 (2000).
3. J. C. Wren, et al., "The Interaction of Iodine with Organic Material in Containment," Workshop on the Chemistry of Iodine in Reactor Safety, Committee on the Safety of Nuclear Installations, Würenlingen, Switzerland, June 10-12, 1996.
4. J. C. Wren, et al., "Modelling Iodine Behaviour Using LIRIC 3.0," Workshop on the Chemistry of Iodine in Reactor Safety, Committee on the Safety of Nuclear Installations, Würenlingen, Switzerland, June 10-12 1996.
5. C. B. Ashmore, et al., "Measurements of the Radiolytic Oxidation of Aqueous CsI Using a Sparging Apparatus," Workshop on the Chemistry of Iodine in Reactor Safety, Committee on the Safety of Nuclear Installations, Würenlingen, Switzerland, June 10-12 1996.
6. E.C. Beahm, et al., "Iodine Evolution and pH Control," NUREG/CR-5950, ORNL/TM-12242, December 1992.
7. W.G. Burns, et al., "The Radiolysis of Aqueous Solutions of Caesium Iodide and Caesium Iodate," AERE- R 13520, ACE-TR-B17, March 1990.

8. P.E.J. Baldwin et al, "A Survey of Wind Speeds in Indoor Workplaces," published by Elsevier Science, Ltd on behalf of the British Occupational Hygiene Society, Annals of Occupational Hygiene, Vol 42. No 5. pp 303-313. 1998.

9. L. Soffer et al, "Accident Source Terms for Light-Water Reactor Nuclear Power Plants, NUREG-1465, February, 1995.

10. E.C. Beahm, "Iodine Chemical Forms in LWR Severe Accidents," NUREG/CR-5732, April, 1992.

11. P. B. Peterson and R. J. Saykally, "Adsorption of Ions to the Surface of Dilute Electrolyte Solutions: The Jones-Ray Effect Revisited," J. Am. Chem. Soc., **127**, 15446 (2005).

12. P. B. Peterson, et al. "Direct Experimental Validation of the Jones-Ray Effect," Chem. Phys. Lett., **397**, 46 (2004).

WorleyParsons Polestar

resources & energy

March 12, 2010

PWR Owners Group
c/o Sean Kinnas
Westinghouse Electric Company

Dear Mr. Kinnas:

On March 8, 2010, WorleyParsons submitted its response to Westinghouse on the NRC Request for Additional Information (RAI) contained in a February 12, 2010 NRC letter from Jonathan Rowley to Anthony Nowinowski. The NRC RAIs addressed the PWR Owners Group submittal of the WorleyParsons Polestar StarFIRE model for calculating iodine re-evolution from engineered safety feature (ESF) leakage pools.

This letter is to formally transmit the RAI response to the Owners Group and to document that the RAI response is non-proprietary.

Very truly yours,

David E. Leaver
Sr. Vice President
WorleyParsons

c: C. Holderbaum, Westinghouse
        B. Grimmel, Westinghouse
        R. Schomaker, Areva