PWROG
PWR Owners Group

Program Management Office
4350 Northern Pike
Monroeville, PA 15146

Project No. 694

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Document Control Desk
U. S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Subject: Pressurized Water Reactor Owners Group - "Response to Question #4 of 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 Document Control Desk, "Submittal of PSAT4025CF.QA.04, Rev 1, StarFIRE Model Report (Proprietary) OG-08-165, May 6, 2008

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

4. Letter, M. Arey to USNRC Document Control Desk, "Response to NRC Request for Additional Information Regarding the review of Whorley Parsons Polestar StarFIRE Model" (PA-ASC-0302), OG-10-107, March 18, 2010

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

Responses to all referenced RAIs except #4 were submitted to the staff per reference 4.

Attached to this letter is the industry response to the official RAI #4. This RAI response is 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.

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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,

RJSchomaker

R. J. Schomaker approving for M. Arey

Melvin L. Arey, Jr., 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 Chairman
PWROG Vice-chairman
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J. Rowley, USNRC
S. Rosenberg, USNRC
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RAI 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.

Response

There are several reasons to justify the neglect of any enhanced mass transport of molecular iodine that might exist due to evaporation of water from the surface of the pool.

The primary reason is the fact that the existing StarFIRE model provides significant conservatism, enough to neglect the effect of water evaporation as demonstrated below:

In equation 4.17 of the model report, we defined a decontamination factor (DF) for the boundary layer as:

$$DF = \frac{[I_2]_{gi}}{[I_2]_{gb}} = 1 + \frac{\dot{V}}{h_D A}$$

where $[I_2]_{gi}$ and $[I_2]_{gb}$ are the iodine gas concentrations at the pool surface and the bulk, respectively, $\dot{V}$ is the ventilation rate, h_D is the mass transfer coefficient of iodine, and A is the pool surface area. In evaluating the boundary layer DF, a Monte Carlo simulation was performed, in which $\dot{V}$ is assumed to vary from about 33 to 26000 cfm. The minimum DF (~14 in the case of the 100,000 trial Monte Carlo in the model report) corresponds to low (near minimum) ventilation rate and high (near maximum) mass transfer coefficient and pool surface area. As we know typical ventilation rates for PWR auxiliary buildings are in the tens of thousands of cubic feet per minute. As seen from the above equation, when the ventilation rate is increased to the range of 10,000 to 30,000 cfm (more realistic values) from 33 cfm (an unrealistically small value chosen to minimize the DF) while keeping everything else the same, boundary layer DF will increase by ~300 to 1000 times. This does not include the conservatisms in the calculation of mass transfer coefficient and the assumption of maximum pool surface area.

It should be pointed out that if the ventilation were about 30 cfm, one would get a lower minimum DF (~14), but there would also be a much lower iodine leakage to the environment since the leakage is proportional to the ventilation rate.

By comparison, the effect of the evaporation of water, if any, on the iodine mass transport (and thus the boundary layer DF) is expected to be small (of the order of a factor of 3 or less based on water vapor diffusivity vs. iodine diffusivity in air), and can be neglected.

Furthermore, it is expected that the rate of evaporation of water from the pool would be small, thus limiting any impact on iodine transport. This is because the pool is expected to be sub-cooled most of the time during the period of interest to us, considering the way the pool is formed, i.e., leaked water accumulating (a few gallons per hour) on a relatively cool surface in a relatively cool atmosphere. The pool will be further cooled by evaporation itself, the most efficient mechanism for removing heat from the pool. The larger the evaporation rate, the faster the pool will be cooled and thus the faster the evaporation rate will be reduced.

Take a simple case as an example. The leak rate is assumed constant and a steady state pool is created by collecting leakage on a surface for t_0 hours at which time the evaporation rate equals the leak rate (neglecting other forms of heat transfer). Thus the rate of change of the pool temperature after t_0 hours is

$$\frac{dT}{dt} \cong \frac{h_{fg}}{c_p t_0}$$

where h_{fg} is the latent heat of evaporation of water, roughly equal to 2.3 million joules per kilogram, and c_p is the heat capacity of water at the constant pressure, roughly equal to 4,200 joules per kilogram per degree Kelvin. If $t_0 = 10$ hr, ${dT}/{dt}$ will be ~50 °C per hour. If the evaporation rate is twice the leak rate, ${dT}/{dt}$ will be ~100 °C per hour initially and increase as the pool water depletes. Thus the evaporation rate is self limiting and will be small either at the beginning or will become small as the pool cools.

Since the partition coefficient increases with temperature, it is conservative to minimize heat removal from the pool. This is the reason we have assumed no evaporation heat transfer. On the contrary, if we consider evaporation, the pool temperature will quickly reach equilibrium with its surroundings which are relatively cool. The lower temperature will then tend to minimize the rate at which aqueous iodine becomes gaseous.