From: Joseph Staudenmeier/NRR
To: George Hubbard
Date: Mon, May 15, 2000 1:49 PM
Subject: draft response to ACRS

my portion of the draft response is attached.

CC: Frank Akstulewicz, Jared Wermiel

4178

Draft response to ACRS letter

The ACRS has identified several phenomena that were not considered in the spent fuel pool heatup analyses. Specifically the staff did not evaluate the impact of zirconium hydride oxidation, breakaway oxidation, zirconium nitride formation, and intermetalic reactions between molten aluminum and either stainless steel or zirconium. These phenomena have the potential to affect both the heatup time to a fission product release and the number of years that the plant is vulnerable to a zirconium fire.

Significant amounts of zirconium hydride can be present in zirconium cladding at high fuel burnups. The zirconium hydride nodules are formed when hydrogen precipitates out of the metal. The nodules migrate to the coldest region of the cladding which concentrates them just inside the oxide layer. The oxidation of zirconium hydride releases 223 kcal/mol of zirconium compared to 260 kcal/mol of zirconium for the oxidation of zirconium metal. The reaction rate of oxygen with zirconium hydride should occur at a rate similar to the reaction of oxygen with zirconium metal since both reactions will be limited by the diffusion rate of oxygen through the oxide layer unless cladding rupture occurs and exposes unoxidized cladding. Additionally the hydrogen totally dissolves into the metal at temperatures greater than 700 C. Therefore the staff believes that the presence of zirconium hydride will not have a major impact on the spent fuel cladding heatup.

Breakaway oxidation occurs when the outer layer of zirconium oxide cracks and/or breaks off. This enhances the transport of oxygen through the oxide layer and therefore increases the reaction rate of oxygen with zirconium. The mechanisms of breakaway oxidation are not entirely understood. Even though the outer layer cracks or breaks away an intact uncracked layer of zirconium oxide of 2-20 mm remains that will prevent air from making direct contact with the zirconium or zirconium hydride. The reaction rate will be limited by the diffusion of oxygen through the intact oxide layer. The staff will perform heatup calulations with under the assumption that the oxide layer remains at a constant thickness of 2-20 mm to evaluate the impact that runaway oxidation will have on heatup rates and critical decay times.

When oxygen is present at concentrations consistent with air it reacts with zirconium at a rate that is approximately 20 times that of the reaction of nitrogen with zirconium. The energy of reaction of nitrogen with zirconium is only one third of the oxygen reaction. Therefore it does not have a significant impact on the heatup calculations. The staff recognizes that the reaction can be significant in oxygen depleted conditions but there are no analyses that depend on the depletion of oxygen for success.

The ACRS is correct in stating that the staff did not consider intermetalic reactions between molten aluminum and either stainless steel or zirconium. The staff will evaluate the impact of these intermetalic reactions. The reaction with stainless steel should be the most important of the two since the aluminum cladding of the boral sheets is in direct physical contact with the stailess steel.

The phenomena discussed above have the potential to alter the 10 hour heatup time at 1 year and the 5 year critical decay time. The staff will perform analyses the determine the impact on these times. In addition the staff is also assessing the impact of partial draindown scenarios on the 5 year critical decay time.