

REQUEST FOR ADDITIONAL INFORMATION  
RELATED TO VOLUME 5 OF PRESSURIZED WATER REACTOR OWNERS GROUP  
TOPICAL REPORT WCAP-17788  
“COMPREHENSIVE ANALYSIS AND TEST PROGRAM FOR GSI-191 CLOSURE”

**RAI-1, Vol 5**

Page 3-2 states that actual projected post-LOCA plant temperature profiles were provided for 26 of 45 test groups. For the remaining test groups an exponential function was used to interpolate between the maximum temperature and the hot leg switchover temperature and time.

- a. Was this function applied to some of the plants that provided time/temperature profiles to verify a reasonable profile fit?
- b. Based on the information provided by plant personnel, there is a wide range of final autoclave test temperatures (e.g., 215 degrees Fahrenheit (°F) Group 15, approximately 100 °F, Group 12). The NRC staff notes that autoclave sample temperatures are subsequently reduced in an oven prior to hot filtering tests (e.g., 160 °F for Group 15, 75 °F for Group 12). While autoclave test temperatures will vary due to differences in plant designs, they may also reflect what individual plants assumed to be conservative. The NRC staff notes that determining a conservative temperature profile is not always straight forward given the competing effects of material dissolution and solubility. Please discuss if there was a consistent basis used for individual plant temperature profiles. In addition, can the data generated by the autoclave test program be used to help evaluate how a different plant temperature profile (e.g., maximum emergency core cooling system (ECCS) trains operation versus one ECCS train operation) would affect their timing of any precipitation reactions ( $t_{chem}$ ) value? In other words, has any analysis been performed to ensure that an intended conservative assumption with respect to temperature profile does not inadvertently produce an unintended non-conservatism in  $t_{chem}$ ?

**RAI-2, Vol 5**

Figure 5-1 provides the change in drain time as a function of aging for precipitate collected after 24 hours for Test 06-07. The topical report (TR) states that decreasing drain times associated with longer hold times is probably caused by a precipitate ripening effect. Please discuss the solution's thermal history during the hold time for Test 06-07 (e.g., held at a constant temperature, cooled to ambient temperature).

**RAI-3, Vol 5**

There are a few cases where it appears the initial test group materials were vastly different than the plant condition. For example, Table F-2 indicates that there is almost a three orders of magnitude reduction in the amount of fiberglass between tests 12-01 and 12-02. Another example is the buffer in test Group 32 was trisodium phosphate for the initial test and sodium tetraborate for subsequent tests. These changes were presumably made after communicating

the detection of potential chemical effects in the initial test to those plants represented by the test group. The NRC staff questions if it is possible for a non-conservative test material error to be made that does not receive additional scrutiny given an acceptable test result. Please discuss any steps that were taken to verify the plant material survey response information.

#### **RAI-4, Vol 5**

Section 5.4 discusses aluminum corrosion for tests with loose debris in a bag relative to out-of-bag. The aluminum corrosion was higher in 27 of 40 cases when the loose debris was contained in a bag. Given that there is variability in how the use of a bag affects the aluminum corrosion and variability in the amount of non-metallic debris (e.g., insulation material) that may be destroyed by a pipe break, please discuss if guidance is being provided to plants on how to interpret the chemical effects test results. For example, the NRC staff considers that it is appropriate to use the more conservative of the "in-bag" and "out-of-bag" tests with respect to precipitation timing when assessing plant-specific conditions since individual pipe breaks may result in big differences in the amount of insulation materials destroyed and transported to the sump pool. Note that the NRC staff does not intend for this statement to apply to cases when the longer out-of-bag filtration time is solely due to physical debris, not chemical precipitates.

#### **RAI-5, Vol 5**

Page 5-34 discusses how the Argonne National Laboratory (ANL) aluminum solubility study predicts precipitation for Test 12-02 at six hours though no precipitation was detected. The TR further states that it is not surprising precipitation was not detected since solution supersaturation can occur and the precipitation of a fraction of the 2.1 parts per million (ppm) aluminum would be hard to detect in both drain tests and in an actual post-LOCA plant situation. Although scaling between tests on a basis of precipitate mass per filter area seems more appropriate than concentration, the NRC staff notes that ANL vertical loop tests with aluminum oxide hydroxide precipitate showed a detectable precipitation mass equivalent to 1 ppm aluminum and precipitation equivalent to 1.5 ppm aluminum (in the ANL loop volume) was capable of clogging a fiberglass bed (see Agencywide Documents Access and Management System (ADAMS) Accession No. ML080600223, Page 6). Was there evidence from the hot filtering tests that there is a threshold quantity of chemical precipitate below which drain times would be less than 100 seconds?

#### **RAI-6, Vol 5**

Group 27 contained a variety of materials, such as calcium silicate and microporous insulation, that made interpretation of out-of-bag test results more difficult. Based on the discussion on Page 6-23 it appears the cooling occurred more rapidly for test OB 27-02 compared to test OB 27-01. Were differences in temperature profiles relative to the filtration times also considered in the evaluation of the Group 27 results to look for conditions that may have favored precipitation?

#### **RAI-7, Vol 5**

The Series 29 tests with high amounts of aluminum produced early aluminum hydroxide type precipitation during all in-bag tests but not during out-of-bag tests, presumably due to silicon inhibition of the aluminum corrosion. During the IBOB Test 29-01, precipitation was delayed to 24 hours. Subsequent Test OB 29-03, run with reduced materials amounts including aluminum, had no precipitates until 24 hours. Volume 5 states that a similar result would be likely for a test

with the reduced amount of materials contained in a bag since the silicon levels during OB 29-03 were less than the in-bag test. While the NRC staff understands the logic behind that statement, the NRC staff questions whether an additional in-bag test with the current plant estimate is needed to provide confidence in the delayed chemical effect result given the testing uncertainties and the consequences of an earlier chemical precipitate.

#### **RAI-8, Vol 5**

Section 6 provides an analysis of uncertainty related to measurement techniques and execution of the autoclave tests, leading to a discussion concerning the probability of chemical effects detection. Another source of uncertainty outside the test program would be variability in the composition and dissolution of plant materials relative to the autoclave test materials. Please discuss if potential differences in heat-to-heat materials (e.g., calcium silicate) should be considered if plants are evaluating a deviation in a direction that increases the risk of precipitation?

#### **RAI-9, Vol 5**

Please provide a re-plot of Figure 7-1 with the maximum x-axis value at 2500 seconds so that the NRC staff can view the transition region in the drain time results more clearly.

#### **RAI-10, Vol 5**

Pages 7-3 and 7-4 discuss a method for evaluating the 100 second drain time as a threshold for determining if chemical effects may have occurred. A conversion factor for the drain tests is developed and a second conversion factor from a previous fuel assembly hot leg break test is used to develop a relationship between drain time in the current tests and pressure drop in the previous hot leg tests. While the NRC staff considers the 100 second drain time to be a reasonable screening criterion for further evaluation of chemical effects, the NRC staff questions the validity of using results from a single fuel assembly test with a totally different test geometry and filter bed. Please discuss if conversion factor 2 would significantly change if other hot leg flow rate test data was used or if cold leg flow rate test data was used instead?

#### **RAI-11, Vol 5**

Figure 7-3 provides evidence for calcium phosphate precipitate formation in Test IBOB 32-02.

- a. The NRC staff was not able to find the chemical analysis and mass of filter results for the IBOB 32-02 test with trisodium phosphate buffer in Tables F-15 and F-17, respectively. Please provide this data.
- b. Given that calcium phosphate precipitates have been shown to settle more quickly than aluminum hydroxide type precipitates, were there any observations of calcium phosphate type precipitates in the bottom of the autoclaves at the completion of the tests? Is it possible that the observed faster filtration times with calcium phosphate type precipitates relative to aluminum precipitates may result from both filtration characteristics and sampling technique due to settlement rates?
- c. Has the PWROG given any consideration to developing a method for plants with TSP buffer to evaluate an unexpected discovery of additional calcium containing material until a point in time when it may be more readily replaced (e.g., during a refueling outage)?

### **RAI-12, Vol 5**

Section 7-4 compares aluminum solubility predictions from ANL studies (ADAMS Accession No. ML080650350) with observations from the PWROG autoclave tests. Subsequent testing at ANL adjusted the solubility estimates to include data from ANL vertical loop tests with aluminum coupons. Please compare the updated ANL aluminum solubility predictions from Equations 3 and 4 (see ADAMS Accession No. ML091610696) with the autoclave precipitation data and evaluate in terms of the aluminum precipitation boundary.

### **RAI-13, Vol 5**

Section 7-6 and Table 7-6 provide guidance for the evaluation of changes in plant conditions/materials from a chemical effects perspective. Please address the following:

- a. Plants are provided two options for determining a new  $t_{chem}$ , either show the change reduces the probability of precipitation or demonstrate there is sufficient margin to precipitation if the plant change results in a greater probability of precipitation. Given the inherent uncertainty associated with a prediction tool such as the precipitation boundary, is the PWROG considering guidance concerning what percentage of the precipitation boundary value provides sufficient margin for early chemical effects?
- b. Should Table 7-6 contain a reminder that it refers to the in-vessel evaluation only and that plant changes also need to be evaluated for impacts to the sump strainer?
- c. The NRC staff questions if some of the parameters discussion within Table 7-6 should be expanded. For example, the coolant pH (post-LOCA pool pH) "Effect of Change" column states "no effect on  $t_{chem}$ ." While the NRC staff acknowledges that increasing pH produces competing effects with respect to aluminum corrosion and solubility, the autoclave data shows pH changes can significantly impact potential plant chemical effects as demonstrated by filtration times (Groups 29, 41). Therefore, the NRC staff considers it appropriate for Table 7-6 to note that a detailed analysis should be performed for plants considering a pH change.

### **RAI-14, Vol 5**

Page 6-14 of Volume 5 notes that measurement of Silicon was performed by another laboratory (Kinectrics). Please discuss the analytical method that was used for these measurements.

### **RAI-15, Vol 5**

Pages 6-2 to 6-4 discuss the percent relative standard deviation (%RSD) of drain time measurements. Please provide the %RSD for the following sets of data:

- a. In-bag drain tests with chemical precipitates present
- b. In-bag drain tests without chemical precipitates present
- c. No bag tests with chemical precipitates present
- d. No bag tests without chemical precipitates present

## **RAI-16, Vol 5**

Section 6.1.3 (page 6-8) discusses measurement uncertainty. Table 6-3 compares the inductively-coupled plasma mass spectrometer (ICP-MS) response of borated and non-borated solutions of nine different metals at concentrations of 100 - 250 parts per billion (ppb). The concentrations of aluminum in the tests performed were mostly greater than 1,000 ppb. The matrix evaluation tests were conducted with pure water standards with and without boron. As the concentration of solids in a matrix increases, the potential matrix effects on the ICP analysis will increase due to an increased time to initial salt formation and subsequent atomization in the plasma.

- a. Would use of higher concentrations of aluminum and calcium (that more closely matched the experimental conditions) been more effective in screening for potential matrix effects?
- b. Silica was not included in the determination of matrix effect. If silica had a significant matrix effect on the ICP-MS measurements, such that it inhibits the response for aluminum, could it impact conclusions based on the measurements of aluminum in solution?
- c. Were the data in Table 6-3 generated using standards that were acidified or standards that were brought to the pH range of 7 - 10 as were the samples that were analyzed for the chemical effects testing?
- d. Were different standard solutions at each concentration used or was one solution used for all the tests at a single concentration (i.e., for five test runs done at 100 ppb were these separately prepared solutions or aliquants from the same stock solution)?

## **RAI-17, Vol 5**

Page E-5 of Appendix E (Step 14), regarding the characterization of the filters by weighing and photographic means:

- a. Would the use of multiple heating cycles to a constant weight at 105 degrees Celsius (standard analytical practice for drying materials, Chapter 6, "Fundamentals of Analytical Chemistry," 3rd Edition, Douglas Skoog and Donald West) have resulted in a lower filter mass? Would this change any conclusions concerning the amount of precipitate formed?
- b. Was the digestion of the filters complete or was there residual material left after completing the microwave digestion method?

**RAI-18, Vol 5**

Please confirm if the following are typographical errors:

- a. For Table 5-2, Table 6-10, and Appendix E, should the mass unit of filtered solids be grams, not milligrams?
- b. Appendices references:
  - Page 5-10 should read "Appendix C"
  - Page 5-39 should read "Appendix A"
  - Page 6-23 should read "Appendix B"
- c. Page 5-23 discussion of Test 24-01 contains an extra "average."
- d. Page 7-4 should read "dividing conversion factor 1 by conversion factor 2"
- e. The Table F-6 entry for IBOB 32-02 should show 23.76 grams of calcium silicate and 59.93 grams for E-glass.