ICET Test #5: Test Conditions and Observations (Sodium Tetraborate and 100% Fibrous Insulation)

Test Conditions

The general conditions, approach, and requirements governing this test are contained within revision 13 of the test plan that governs the ICET program (Adams Accession #ML052100428). All tests are being conducted in environments that represent expected containment pool conditions during recirculation. The initial chemical environment for ICET Test #5 contains 2400 mg/L of boron, and lithium hydroxide (LiOH) to achieve 0.3 mg/L of lithium. Tests are conducted for 30 days at a constant temperature of 60ºC (140ºF). The materials tested within this environment included representative amounts of submerged and unsubmerged aluminum, copper, concrete, zinc, carbon steel and insulation samples. Representative amounts of concrete dust and latent debris were also added to the test solution. The test consisted of an initial four hour spray phase to simulate containment spray interaction with the unsubmerged samples. A 43 mg/L concentration of hydrochloric acid (HCl) was metered into the tank over the last two hours of the spray phase. Water was circulated through the bottom portion of the test chamber during the entire test to achieve representative flow rates over the submerged specimens.

The primary differences among the ICET tests are the buffering agent and the insulation materials. Test #5 incorporated a sodium tetraborate buffering agent and 100 percent fibrous insulation. One hundred forty-three gallons of sodium tetraborate (2100 mg/L boron concentration) was mixed with 107 gallons of boric acid (2800 mg/L boron concentration) to achieve the desired 2400 mg/L boron concentration. The sodium tetraborate was introduced prior to the initiation of sprays within the test chamber. No attempt was made to control pH once the sodium tetraborate was added. The test solution pH was 8.4 prior to initiation of the sprays, after the initial chemical environment had been established. The pH of the test solution decreased slightly during the last two hours of the spray phase to a value of approximately 8.3 due to the HCl addition. The pH remained between 8.2 to 8.3 over the first 20 days of the test and between 8.2 and 8.5 over the final 10 days of the test. This 30-day test was initiated on July 26, 2005, and was completed on August 25, 2005.

Important Test Observations

The following general visual observations were made during the test. Just before spray initiation, and shortly after the latent debris and crushed concrete were introduced into the tank, the inline flow meter became clogged and ceased to work. The unit was removed, rinsed with reverse osmosis water, and returned to service. The flow meter operated normally after this point and the test was initiated. Four hours after the sprays were activated, the test chamber solution was turbid and it was difficult to see the submerged coupons from the lower viewport window. By day six of the test, water clarity had improved enough to see the opposite side of the test chamber through the lower viewing window.

On day 10 of the test, very small white particles were observed on the submerged galvanized steel coupons while all remaining coupons appeared similar to their pre-test condition. However, by day 22 of the test, the submerged aluminum specimens had a rough, dull surface coating similar in appearance to the inorganic zinc-coated steel coupons. A total of 23 gallons of reverse osmosis water was added in either three or five gallon increments over the course of the test to account for test solution evaporation and daily sample extraction.

Several samples are being evaluated for the presence of chemical effects in these tests: the test solution, fibrous insulation samples, test chamber sediment, and sample coupons. There is currently evidence of chemical by-products in the test solution, fibrous insulation samples, sediment, and sample coupons, all of which should be considered when addressing possible chemical effects implications as part of the generic letter (GL) 2004-02 evaluation. The test observations relevant to each sample types are described as follows:

Water Samples

No chemical by-products were visible at the test temperature of 140°F during this test. At room temperature, precipitants became visible at the bottom of water samples beginning with the day 2 sample. The amount of visible room temperature precipitation appear to increase slightly in each subsequent daily water sample. It should be noted that it takes several days at room temperature before the precipitants are apparent at the bottom of the samples bottles. The total amount of precipitant in the day 30 water sample barely covers the bottom of the 250 ml sample bottles. This is much less precipitant than was apparent in ICET Test #1. When the precipitants are suspended upon shaking, they are not visible anymore and it takes approximately 2 to 3 days before they settle back to the bottom of the sample bottles.

Total suspended solids (TSS) were measured during the test. The baseline TSS prior to the initiation of sprays was 16 mg/L. At the conclusion of the spray phase, the TSS value was approximately 26 mg/L. The TSS then decreased until day 5 when the TSS was approximately 17 mg/L. From days 5 through 9 of the test the TSS remained approximately constant with an average value of 17 mg/L. The TSS at day 10 then increased to a value of 25 mg/L. Between days 10 and 21, the average TSS value was greater than 20 mg/L, but results were more variable. Individual measurements ranged from a low of 16 mg/L to a high of 32 mg/L during this time-frame. After day 22, the TSS measurements decreased to approximately 15 mg/L and remained approximately constant over the duration of the test.

The bulk kinematic viscosity measurements at 60°C and 23°C averaged 0.49 and 0.94, respectively, over the test duration. The 60°C values remained constant during the test. The 23°C measurements appear to be constant over the first 15 to 17 days of the test. Between days 16 to 18, viscosity slightly increases to approximately 0.96 and remains constant until the end of the test.

The turbidity values taken before the latent debris and concrete dust were added was less than 1 NTU at both 60°C and 23°C. After addition of the latent debris and concrete dust samples, the turbidity at 60°C increased to 14 NTU at the start of the test. During the 4-hour spray phase, the turbidity at 60°C slowly decreased to 12 NTU at the end of the spray phase. As the test continued, the turbidity measurements at 60°C continued to decrease and were less than 1 NTU by day 8. The 60°C values generally remained below 1 NTU for the remainder of the test and had an average value of 0.7 NTU between days 8 and 30. The turbidity measurements at 23°C were similar to the 60°C values through day 7 of the test. Beginning at the day 8 measurement, however, the 23°C values began to deviate from, and were slightly higher than, the 60°C values. Between days 12 and 14, the 23°C turbidity measurements began to increase to a value of approximately 5 NTU by day 18 of the test. For the remainder of the test, the average 23°C turbidity value remained approximately 5 NTU.

Concentrations of important elements were monitored during the test. The measured concentrations subsequently reported are still being evaluated to ensure that reported trends are consistent with other observations and findings. The sodium concentration was approximately 1200 mg/L between days 1 through 17 of the test. On day 18, the sodium concentration had increased to 1400 mg/L and remained at this value through the day 20 analysis. Between days 20 and 30 of the test, the sodium concentration gradually decreased to a value of approximately 1200 mg/L by the end of the test. The aluminum concentration was initially minimal and then rose to approximately 55 mg/L after approximately 12 days of testing. The day 15 measurement indicated a sudden drop in the aluminum concentration to approximately 45 mg/L. The aluminum remained below 50 mg/L between days 15 and 20. The day 21 measurement indicated that the aluminum concentration had dropped again to 37 mg/L. Beginning at the day 23 measurement, the aluminum concentration rose from 35 mg/L to 45 mg/L by the end of the test.

Calcium and silica were also measured during Test #5. The calcium concentration initially was minimal, but it rose to a value above 15 mg/L by day 2, and reached 20 mg/L by day 6. The calcium concentration peaked by day 11 at approximately 22 mg/L and at day 15 decreased slightly to 20 mg/L. Between days 15 and 24, the concentration remained approximately constant at 20 mg/L. The day 25 measurement indicated that calcium had increased to 30 mg/L and it remained above this value for the remainder of the test. The initial silica concentration at test initiation was approximately 6 mg/L; it rose to 10 mg/L by the end of the spray phase and peaked at 12 mg/L by day 3 of the test. The concentration slowly decreased beyond day 3 until it reached a value of 7 mg/L by day 22. The silica concentration remained below 8 mg/L between days 22 and 30 of testing.

Minimal or no concentrations of iron, lead, nickel, and potassium were present during the test. Copper and magnesium concentrations were approximately 1 mg/L during the test. Zinc concentrations were initially approximately 1 mg/L, but decreased by day 4 of the test to less than 0.2 mg/L. Zinc concentrations remained below this level throughout the remainder of the test. Chloride concentrations were initially low as well, but rose to a value of 40 mg/L after the 4 hour spray phase. The concentrations remained approximately constant over the remainder of the test.

Fibrous Insulation Materials

Fibrous insulation materials are being evaluated that were extracted from the tank during the beginning, middle, and end of the test. Initial evaluations revealed that some web-like structures formed between the fibers intersection points. These structures were evident in the day 4, day 15 and day 30 insulation samples. However, preliminary evaluation indicates that the quantity of these structures is less than in previous ICET Tests #1 - #3.

Sediment

There was a small quantity of sediment found on the test chamber floor in addition to the latent debris and concrete dust quantities added just before the onset of testing. The sediment quantity initially appears to be similar to earlier ICET Tests #1 and #2. Much of this additional sediment appeared to be from fugitive insulation material that escaped from the insulation sample bag during testing. More detailed analysis of the sediment for evidence of corrosion by-product formation is underway.

Sample Coupons

The samples were weighed after drying and no cleaning was performed prior to weighing. Weight loss/gain measurements indicate that only the submerged aluminum specimens experienced a significant weight change. The submerged aluminum specimens lost approximately 5 percent of their pre-test mass. The concrete sample gained 226 g (3% of its pre-test mass). The concrete weight gain may have resulted from retained water after several days of air drying. Other samples either gained or lost less than 1 percent of their pre-test mass.

A more complete data report for ICET Test #5, containing additional observations, is currently being prepared and will be made publicly available once it has been completed.