



South Texas Project Electric Generating Station P.O. Box 289 Wadsworth, Texas 77483

November 23, 2010  
U7-C-STP-NRC-100250

U. S. Nuclear Regulatory Commission  
Attention: Document Control Desk  
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South Texas Project  
Units 3 and 4  
Docket Nos. 52-012 and 52-013  
Response to Request for Additional Information

Attached are the responses to NRC staff questions included in Request for Additional Information (RAI) letter number 364 related to Combined License Application (COLA) Part 2, Tier 2, Appendix 6C.

The attachments address the responses to the RAI questions listed below:

RAI 06.02.02-29  
RAI 06.02.02-30

There are no commitments in this response.

If you have any questions regarding this response, please contact me at (361) 972-7136, or Bill Mookhoek at (361) 972-7274.

DO91  
NRO

STI 32784753

I declare under penalty of perjury that the foregoing is true and correct.

Executed on 11/23/10



Scott Head  
Manager, Regulatory Affairs  
South Texas Project Units 3 & 4

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Attachments:

1. RAI 06.02.02-29
2. RAI 06.02.02-30

cc: w/o attachment except\*  
(paper copy)

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**RAI 06.02.02-29****QUESTION:**

The June 10, 2010, response, to RAI 06.02.02-27 states that the corrosion products from zinc are expected to be particulate, and that no new type of chemical precipitate would result from zinc (i.e., a type of precipitate different than the particulate evaluated for the reference Japanese ABWR). Please provide the technical basis for stating there will be no new type of precipitate, such as a gel-like precipitate. The next paragraph provides background information from the staff and is part of the basis for the need for additional information from the applicant.

It appears that the zinc in inorganic zinc (IOZ) coatings may corrode in a post-LOCA environment, but there is limited information about the rate and the form of the corrosion product. For example, the report from the Erlangen Tank Test Station (ML083510156) described pressure loss from an accumulation of zinc corrosion products in a mineral wool bed. The source of the zinc in that test was galvanized steel, but the zinc in IOZ coatings may also be subject to dissolution (corrosion) depending on water chemistry and temperature (e.g., NUREG-6873 and NUREG-6988). WCAP-16530-NP-A included a pH- and temperature-dependent corrosion-rate equation for zinc based on the test results for galvanized steel, but the amount was considered negligible for operating PWRs and not included in the chemical model. The Utility Resolution Guidance recommendation of 47 pounds of particles from IOZ coatings did not consider chemical dissolution (corrosion) of the zinc and subsequent precipitation in another form. The staff notes one source showing the solubility of amorphous and crystalline zinc hydroxide phases decreases by about four orders of magnitude when the pH increases from 7 to 9 at 25°C (Marcel Pourbaix, "Atlas of Electrochemical Equilibria in Aqueous Solutions," National Association of Corrosion Engineers, 1974).

**RESPONSE:**

The only source of zinc inside the STP 3&4 primary containment is the assumed destroyed inorganic zinc (IOZ) primer from the qualified coating within the high energy line break (HELB) zone of influence. STP 3&4 design specifications prohibit the use of galvanized steel and any other source of zinc in the primary containment. The IOZ primer exists as 80% zinc particles and 20% zinc oxide particles (Reference 1). The corrosion of zinc in an aqueous environment yields zinc oxide, which, like zinc, is also a particulate for the elevated temperatures expected in the post-LOCA suppression pool (References 1 and 2). Because it is possible that the suppression pool temperatures may be lower than the temperature transient that is typically the bounding case (i.e., highest temperatures), it is possible that the zinc corrosion products that are produced during the 30-day post-LOCA period may not be particulate. To bound this possibility, such corrosion products will conservatively be assumed to be gelatinous instead of particulate.

Westinghouse has performed a calculation of the quantity of the postulated 47 lbs. of zinc in the destroyed coatings primer that would corrode over 30 days during the bounding post-LOCA temperature profile (highest corrosion rate). The calculation of the amount of zinc released is

based on the methodology developed in WCAP-16530-NP-A. The corrosion rate is a function of exposed surface area. The 47 lbs. of IOZ primer (which was assumed to be 604 sq. ft. of 0.005 in. thick primer before destruction) is assumed to be 10 micron spheres after destruction, which translates into a total surface area of 22,653 sq. ft. The calculation was performed for a pH of 5.3, which is the minimum allowable pH for the STP 3&4 licensing basis, and for a pH of 8.9, which is the maximum allowable pH for the STP 3&4 licensing basis (Reference DCD Tier 2, Subsection 3I.3.2.3). The use of a maximum and minimum pH will provide for the evaluation of the maximum amount of corrosion products as the corrosion of zinc increases with decreasing pH and the corrosion of aluminum increases with increasing pH. The calculation of corrosion products at limiting pH values and the use of the maximum amount of corrosion products provides for a conservative input to the fuel debris capture testing.

The time-dependent post-LOCA suppression pool temperature is based on that calculated for the STP 3&4 containment design analysis in WCAP-17058-P for the time period up to 13.89 hours, where that calculation ended. From 13.89 hours to 30 days, the temperature was assumed to vary linearly from the temperature at 13.89 hours to the maximum allowable normal operating suppression pool temperature of 95°F.

As noted earlier in the response, two pH values were considered: a pH of 5.3 (minimum licensing basis limit) and a pH of 8.9 (maximum licensing basis limit). Based on a 22,653 sq. ft. of exposed surface area of zinc, a constant value of pH, the time-dependent suppression pool temperature post-LOCA, and the corrosion rates described in WCAP-16530-NP-A, the amount of zinc that becomes corrosion product is 21.3 kg at pH = 5.3 and 5.0 kg at pH = 8.9. Based on this amount of corroded zinc, the total amount of zinc oxide corrosion product is 26.6 kg at pH = 5.3 and 6.2 kg at pH = 8.9. The WCAP-16530-NP-A corrosion rates for zinc are applicable to STP 3 & 4 for the following reasons:

- The test used galvanized steel coupons. The galvanizing material is a coating of elemental zinc on the carbon steel coupon. The use of a galvanized surface maximized corrosion rates compared to zinc primer.
- Testing was conducted at a range of pH values and temperatures, covering the range of such conditions that might occur for STP 3 & 4.
- The duration of the tests was sufficiently short in time as to preclude the development of a passivation layer on the coupons, i.e., there was no mechanism to reduce the rate of zinc corrosion of the galvanized surfaces.

Thus, the corrosion rates from the testing of galvanized steel coupons reported in WCAP-16530-P-A are taken to be conservative compared with those that would be expected for post-LOCA conditions in STP 3 & 4.

Conservatively, no credit is taken for solubility of the zinc corrosion products, or the remaining particulate zinc.

For the downstream effects on fuel testing, the maximum corrosion product source term from the two pH calculations will be used. All of the corrosion products, including the non-particulate

zinc corrosion product, will be represented by the same mass of aluminum oxyhydroxide. The use of this material as a surrogate for zinc corrosion products is based on the finding reported by Argonne National Laboratory that the aluminum oxyhydroxide generated using the method of WCAP-16530-NP-A (Reference 3) resulted in higher pressure drops compared to the other corrosion products considered in the Argonne work (Reference 4).

The impact of zinc non-particulate precipitate on the STP 3&4 suction strainer head loss is minimal because:

- Fibrous materials in the STP 3&4 containment that could provide a fiber bed for accumulation of this precipitate is limited to latent fibrous debris, and this amount does not result in the formation of a contiguous fiber bed, and
- The amount of precipitate generated is small, which provides for a correspondingly small loading of non-particulate zinc precipitate debris on the large recirculation screen area.

The COLA changes to Appendix 6C will be included in the response to RAI 04.04-04.

#### References

1. Metals Handbook, Ninth Edition, Volume 13 Corrosion. ASM International Handbook Committee. Metals, Park, Ohio, 1987.
2. Zhang, Xiaoge Gregory. Corrosion and Electrochemistry of Zinc. New York: Plenum Press, 1996.
3. WCAP-16530-NP-A, "Evaluation of Post-Accident Chemical Effects in Containment Sump Fluids to Support GSI-191," Ann E. Lane, Timothy S. Andreychek, William A. Byers, Richard J. Jacko, Edward J. Lahoda, and Richard D. Reid, Westinghouse Electric Company LLC, March, 2008.
4. "Technical Letter Report on Evaluation of Head Loss by Products of Aluminum Alloy Corrosion," C. B. Bahn, K. E. Kasza, W. J. Shack, and K. Natesan, Argonne National Laboratory, August 11, 2008.

**RAI 06.02.02-30****QUESTION:**

The July 21, 2010, response, to RAI 06.02.02-27 described laboratory testing performed for South Texas Project 3 & 4 to determine if sodium aluminum silicate would precipitate in the postulated post-LOCA environment. Please provide the following additional information about this testing:

- a) Describe the basis for performing a test designed to measure dissolution of an existing solid rather than a test designed to detect the formation of the precipitate from solution.
- b) Explain how the sodium aluminum silicate used in the South Texas Project 3 & 4 benchtop testing is equivalent to the sodium aluminum silicate precipitate ( $\text{NaAlSi}_3\text{O}_8$ ) modeled in WCAP-16530-P-A. The chemical used in the STP 3 & 4 solubility tests is described in the Sigma-Aldrich Material Safety Data Sheet as “aluminum silicate” and “silicic acid, aluminum sodium salt.” The highly hydrated  $\text{NaAlSi}_3\text{O}_8$  precipitate generated according to WCAP-16530-NP is prepared from aluminum nitrate and sodium silicate. It is not clear to the staff that the two aluminum solids are identical, or at least equivalent in terms of their dissolution/precipitation characteristics.
- c) Describe how the experimental procedure accounts for precipitates less than the 0.45 micrometer ( $\mu\text{m}$ ) filter size. It is not clear to the staff that the measured cation concentrations accurately or conservatively represent the concentrations at the test conditions. Prior testing under the GSI-191 program has concluded that aluminum-based precipitates may be less than 0.2  $\mu\text{m}$  in size and cause high head losses in laboratory testing.

**RESPONSE:**

- a) The purpose of the STP 3&4 bench test described in this RAI is to determine an aluminum solubility limit. Sodium aluminum silicate (SAS) to ion products is a reversible reaction. At equilibrium, the forward, or dissolution, reaction is equal to the reverse, or precipitation, reaction. The soluble aluminum ion concentration at equilibrium is the same for either case. References 1 and 2 show that the dissolution of major cations increases very rapidly within the first 24 hours and then increases slowly, reaching equilibrium after 24 days. For albite, a SAS, the aluminum concentration in solution after 1 day appears to be about 10% of the final concentration after 24 days. Because the aluminum solubility determined in the STP 3&4 bench testing was based on the measured aluminum concentration after 1 day of exposure, this indicates that the measured solubilities reported for that test are conservative.
- b) The two aluminum solids, as noted in the RAI, are not identical. The material that was used in WCAP-16530-NP-A was freshly prepared and would have yielded higher aluminum solubility than aged material. The STP 3&4 bench test program used aged material. Therefore, the STP 3&4 bench test yields a conservative value of solubility for aluminum.

- c) The 0.45 micron filters used in the STP 3&4 bench tests are the industry standard to separate soluble and insoluble fractions. This information is included in EPRI Report No. 1014986, "Pressurized Water Reactor Primary Water Chemistry Guidelines," Volume 1, Rev 6, page F-3, dated December 2007. Thus, the 0.45 micron filters are consistent with industry practice.

The filter used for the WCAP-16530-NP-A work was a 1 micron filter. Thus, had the same sized filters used for the WCAP 16530-NP-A work been used in the STP 3&4 bench testing, the result would have been a higher apparent aluminum solubility because more precipitate would pass through the filter and show up as soluble aluminum. The use of the 0.45 micron filter in the STP 3&4 bench tests is therefore conservative.

In summary, the purpose of the STP 3&4 bench test program is to assess aluminum solubility, not to assess head loss across a debris bed. To that end, the use of aged material that results in lower solubility and the use of an industry standard filter size provide assurance that the recent test program yields a conservative value for aluminum solubility.

The above testing conservatively demonstrates that, with 4.5ft<sup>2</sup> of aluminum exposed to recirculating coolant post-LOCA, the amount of dissolved aluminum in solution will be under the solubility limit for aluminum by at least a factor of 10 from the minimum solubility limit. With controls in place to assure the latent aluminum does not exceed the equivalent of an aluminum surface area of 4.5 ft<sup>2</sup>, the amount of dissolved aluminum is not expected to exceed this minimum solubility.

However, STPNOC will include aluminum chemical precipitates in downstream fuel effects testing. The amount of precipitate for this testing will be based on the following conservative assumptions;

- All of the aluminum that corrodes and forms SAS and aluminum oxyhydroxide will exist in precipitate form and not remain dissolved in solution. (Note that not taking credit for the solubility of aluminum oxyhydroxide is a change from previous RAI responses, and it is being made to resolve NRC concerns about potential post-LOCA suppression pool pH profiles.)
- All of the corrosion products from zinc coatings will form precipitate that will be represented by an equal mass of aluminum oxyhydroxide.

The calculation of the amount of these corrosion products is based on the methodology developed in WCAP-16530-P-A and includes the following assumptions:

- (1) The surface area of submerged aluminum is 4.5 ft<sup>2</sup>. This is conservative because there is no aluminum allowed in the STP 3&4 containment and the only credible source of aluminum is latent aluminum. As noted in the response to RAI 06.02.02-11 Supplement 2 (STPNOC Letter No. U7-C-STP-NRC-100044 dated February 22, 2010), the implementation of the STP 3&4 suppression pool cleanliness and Foreign

Material Exclusion (FME) programs will ensure that latent aluminum quantities would be less than this amount.

- (2) The mass of submerged aluminum is 10,000 lbs. This conservatively high value was chosen to ensure there is sufficient aluminum to continue the reaction.
- (3) Two pH values are assumed in the calculations. For the first calculation, the pH assumed for the entire 30-day post-LOCA period is the maximum allowable design basis limit of 8.9 (Reference DCD Tier 2 Subsection 3I.3.2.3). As shown in Table 06.02.02-27-1 of the supplemental response to RAI 06.02.02-27 (STPNOC Letter No. U7-C-STP-NRC-100173 dated July 21, 2010), aluminum corrosion rate increases with higher pH, so this is a conservative assumption. A second calculation assuming a pH = 5.3, the minimum allowable design basis limit, is assumed for the entire 30-day post-LOCA period (Reference DCD Tier 2 Subsection 3I.3.2.3). This is conservative for zinc as zinc corrosion increases with decreasing values of pH. The amount of corrosion products for the downstream fuel effects testing is based on the higher total mass of combined zinc and aluminum corrosion products for these two pH extremes.
- (4) The time-dependent post-LOCA suppression pool temperature is based on that calculated for the STP 3&4 containment design analysis in WCAP-17058-P for the time period up to 13.89 hours, where that calculation ended. From 13.89 hours to 30 days, the temperature was assumed to vary linearly from the temperature at 13.89 hours to the maximum allowable normal operating suppression pool temperature of 95°F.
- (5) The area of exposed concrete is 302 ft<sup>2</sup>. The conservatism of this assumption is discussed in the response to RAI 06.02.02-31 (STPNOC Letter No. U7-C-STP-NRC-100233 dated October 14, 2010.)
- (6) A total surface area of 22,653 sq. ft. of elemental zinc from inorganic zinc coatings (From the response to RAI 06.02.02-29).

The results of this calculation show that, at the pH value of 5.3 when total corrosion products are a maximum, the quantity of SAS precipitate is 0.01 kg, the quantity of aluminum oxyhydroxide precipitate is 0.05 kg and the quantity of zinc oxide precipitate is 26.6 kg. The downstream fuel effects tests will simulate the combined mass of these three corrosion products as aluminum oxyhydroxide, based on the higher head loss exhibited by aluminum oxyhydroxide versus SAS.

The impact of SAS and aluminum oxyhydroxide precipitate on the STP 3&4 suction strainer head loss is minimal because:

- Fibrous materials in the STP 3&4 containment that could provide a fiber bed for accumulation of this precipitate is limited to latent fibrous debris, and this amount does not result in the formation of a contiguous fiber bed, and

- The amount of precipitate generated, as noted above, is small, which provides for a correspondingly small loading of SAS and aluminum oxyhydroxide precipitate debris on the large recirculation screen area.

Therefore, the head loss testing performed for the RJ-ABWR suction strainers, which includes such materials as fiber and calcium silicate which are prohibited at STP 3&4, remains a valid design basis for the STP 3&4 suction strainers.

A COLA markup providing a revision to Appendix 6C, which will include the amount of SAS and aluminum oxyhydroxide to be simulated in the downstream fuel effects test, will be provided as part of a supplemental response to RAI 04.04-4.

#### References

1. Wen H. Huang and Wen C. Kiang, American Minerologist, Volume 58, pages 1016-1022, 1973.
2. W. H. Huang and W.C. Kiang, American Minerologist, Volume 57, pages 1849-1859, 1972.