Considerations for using Zinc in Refined GSI-191 Chemical Effects Testing

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Background

Chemical effects testing for the Vogtle and Calvert Cliffs GSI-191 projects [Ref. 1 & 2] revealed that the presence of zinc in a post-LOCA pool could also reduce the release of aluminum from the dissolution of fibrous insulation and the corrosion of metallic aluminum. Because aluminum is a primary concern for chemical precipitates in nuclear power plants with large quantities of fibrous insulation such as Calvert Cliffs, the modeling of zinc in chemical effects tests must be carefully considered to avoid over loading the tests with zinc which could reduce the release of aluminum.

There are two main sources of zinc in a Nuclear Power Plant containment:

- Galvanized steel from gratings, HVAC ducts and miscellaneous structural members; and
- Inorganic zinc (IOZ) particulates from zinc rich coatings.

Once the quantities of either source are calculated, the issues then become the nature of the debris formed and how to scale for chemical effects testing. Scaling of galvanized steel is straightforward since actual galvanized steel gratings or galvanized steel ducting material can be used. Scaling of zinc rich coatings is not as straightforward as galvanized steel.

Failed IOZ coatings historically have been modeled as 10 μm spheres for hydraulic characteristics in debris bed head loss testing. The use of IOZ particulate in chemical effects head loss testing is problematic as the IOZ particles are difficult to contain and tend to transport to the debris bed which increases debris bed head loss through mechanical influences thereby masking debris bed head loss increases caused by chemical effects.

An alternate modeling approach for chemical effects testing is to use zinc plate with a surface area scaled based on the surface area of the quantity of 10 μm spheres of failed IOZ. This modeling approach was used in early chemical effects autoclave testing for Calvert Cliffs and it was determined that this modeling approach resulted in an unrealistically large and non-prototypical surface area of metallic zinc. Therefore an alternate modeling approach is proposed to address the non-prototypicality.

Zinc Rich Coatings

The following are the types of zinc rich coatings exist in the Calvert Cliffs containment buildings:

- Qualified zinc rich coating with qualified epoxy top coat
- Unqualified and degraded qualified epoxy top coated zinc rich coating
- Unqualified zinc rich coating with no epoxy top coat

The following are the responses of the three types of zinc rich coating types following a LOCA and the recommended zinc rich modeling technique for chemical effects testing:

1. Qualified zinc rich coating with qualified epoxy top coat.
    - Qualified zinc rich coatings outside a HELB ZOI will not be source of zinc since they will not fail or release zinc. No qualified zinc rich coatings outside the ZOI should be included in chemical effects testing.
    - Qualified zinc rich coatings within the ZOI are assumed to fail by erosion [Ref. 3, Appendix A] removing a portion of the IOZ primer with the remainder remaining on the substrate. These failed coatings will be modeled with IOZ coated coupons with a surface area of twice the surface area in the ZOI. One-half of this surface area represents the IOZ remaining on the substrate and will be modeled submerged or subject to spray depending on the location of the coated surface. The other half of this surface area represents the eroded IOZ and will be modeled as submerged in the pool. The coupons shall be coated in accordance with Reference 4 and cured for 48 hours at 50% RH or greater and 70°F or greater in a CO_2 rich atmosphere.

2. Unqualified and degraded qualified epoxy top coated zinc rich coating.
    - Unqualified and degraded qualified epoxy top coated zinc rich coatings within the ZOI are also assumed to fail by erosion [Ref. 3, Appendix A] removing a portion of the IOZ primer with the remainder remaining on the substrate. These failed coatings will be modeled with IOZ coated coupons with a surface area of twice the surface area in the ZOI. One-half of this surface area represents the IOZ remaining on the substrate and will be modeled submerged or subject to spray depending on the location of the coated surface. The other half of this surface area represents the eroded IOZ and will be modeled as submerged in the pool. The coupons shall be coated in accordance with Reference 4 and cured for 48 hours at 50% RH or greater and 70°F or greater in a CO_2 rich atmosphere.
    - Unqualified and degraded qualified epoxy top coated zinc rich coatings outside the ZOI are assumed to fail as a delamination of the epoxy top coat in the form of chips. The zinc coating will be firmly adhered to the substrate and the back side of the epoxy topcoat. These observations are based on experiments conducted for

Comanche Peak [Ref. 5, Pg. 21] zinc using samples of the containment epoxy topcoat / inorganic zinc rich primer which had failed in service. The coating system failure was determined to be the result of excessively thick inorganic zinc rich primer coated with excessively thick epoxy topcoat. Examination of Comanche Peak failed coating samples showed that the epoxy peeled due to excessive shrink stresses, and approximately 4 mils thickness of zinc particulates were found attached to the underside of the epoxy layer. Three to four mils thickness of sound inorganic zinc rich coating was determined to remain attached to the steel substrate at the failure sites. These failed coatings will be modeled with IOZ coated coupons with a surface area of twice the surface area of the coatings. One-half of this surface area represents the IOZ remaining on the substrate and will be modeled submerged or subject to spray depending on the location of the coated surface. The other half of this surface area represents the eroded IOZ and will be modeled as submerged in the pool. The coupons shall be coated in accordance with Reference 4 and cured for 48 hours at 50% RH or greater and 70°F or greater in a CO_2 rich atmosphere.

3. Unqualified zinc rich coatings with no epoxy top coat are urethane resin zinc rich coatings applied to steel providing both galvanic and barrier protection. The failure of these coatings would be the dissolution of the binder releasing the 10 micrometer zinc dust.
    - Coupons with zinc rich coating with the same unqualified coating(s) as used at Calvert Cliffs with the same thickness are an appropriate surrogate for chemical effects testing. The prepared coupons shall be cured in accordance with vendor recommendations for full cure.
    - Zinc plate can be used in lieu of coupons. The zinc plate surface area is scaled based on calculating the surface area of the quantity of 10 μm spheres of zinc powder.

Reference:

1. "Bench Tests Results for Series 3000 Tests for Vogtle Electric Generating Plant", CHLE-SNC-007, Revision 2, Southern Nuclear Company, January 15, 2014.
2. "Plant-Specific GSI-191 Autoclave Chemical Effects Testing for Calvert Cliffs Nuclear Power Plant", WCAP-17892-P, Revision 0-A, Westinghouse Electric Company, April, 2014.
3. "Pressurized Water Reactor Sump Performance Evaluation Methodology", NEI 04-07, Revision 0, December, 2004.
4. "Specification for the Safety-related Level 1 coating Applications inside reactor Containment Building", CCNPP Design Specification No, SP-0898, Revision 2.
5. "Design Basis Accident Testing of Coatings Samples from Unit 1 Containment, TXU Comanche Peak SES", Keeler & Long Report No. 06-0413, April 13, 2006.