Theoretical Considerations on Corrosion of Protective Coatings in Nuclear Power Plant

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1. Introduction

The protective coating paints used in nuclear power plants can be classified as zinc and epoxy. Zinc is mainly used for equipment that emits high-temperature heat due to its high melting point, while epoxy has excellent electrical properties, adhesion, mechanical strength, and chemical resistance, making it the main raw material for structural (concrete, CLP) protection coatings.

In general, the protective coatings of nuclear power plants consist of three layers of concrete primer, intermediate layer, topcoat as one painting system, with all three layers being applied using epoxy. For steel, there are two layers primer and topcoat as one painting system, and zinc is used depending on the substrate temperature.

In this paper, we analyzed the degradation mechanism of epoxy and zinc used in nuclear power plants, and derived appropriate methods for coating based on external changes when exposed to design basis accident conditions in nuclear power plant environments.

2. Research Methods

The protective coating used in the cooling water system of nuclear power plants must pass environmental qualification tests as specified by current regulatory guidelines. The regulations for these tests are based on Reg. Guide 1.54 and follow detailed test specifications outlined in ASTM standards. To evaluate the performance of the protective coatings, there is a high-radiation resistance test and a DBA (Design Basis Accident) test that involves exposing them to conditions expected during a design basis accident, such as high temperature, pressure, chemicals, and flooding environments.

2.1 Temperature, pressure and chemicals

The coating materials inside containment buildings must be proven through tests and analyses to maintain their safety functions during and after chemical agents are sprayed. The performance of coatings in environments where chemical agents are sprayed should be verified under accidental pressure and temperature conditions. If material analysis is performed on the coatings, consideration should be given to analyzing the increase in reaction rate of spraying solutions due to an increase in temperature.

2.2 Flooding

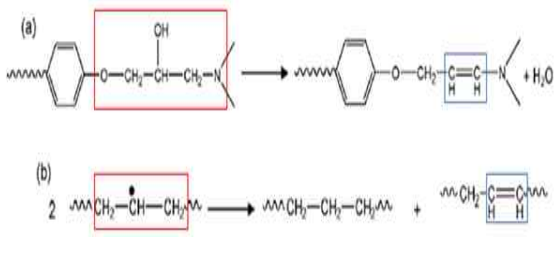
Nuclear power plant primary equipment is installed to provide protection against flooding by locating them above the flood level or sealing them in such a way that they can withstand water ingress. However, protective coatings must also be considered for their integrity during flooding as there will still be areas susceptible to flooding. The water entering these areas contains acids and corrosive substances as well as other contaminants which flow down the surfaces of equipment and structures within the first containment building.

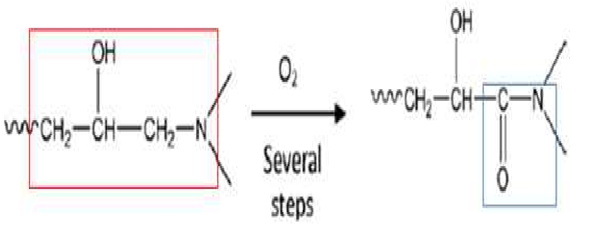
2.3 Radiation

Radiation exposure, which causes degradation of paint coatings, is also part of the verification tests. The protective coating is exposed to radiation equivalent to an accident dose before being subjected to simulated LOCA conditions. For simplicity purposes, both normal operating doses and accidental doses are often combined and treated as one overall required dose that is irradiated onto the test specimens by the testing equipment.

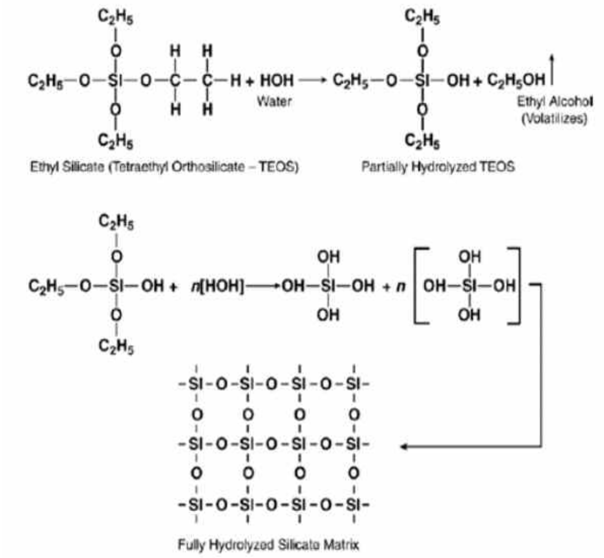
3. Epoxy and Zinc Corrosion Mechanism

Epoxy resins used in nuclear power plants undergo degradation mainly due to thermal initiation and radiochemical initiation caused by heat and radiation respectively.





Inorganic zinc is used in safety level I for self-curing solvent-based alkyl silicates types with the formula (C2H5)4SiO4, where water acts as a reactant and undergoes polymerization reaction.



4. Test Results

The radiation exposure test resulted in discoloration but no delamination, peeling, or uniform deterioration occurred.
In the DBA test, zinc-coated steel specimens on the substrate experienced delamination and blistering, while there was no degradation observed for epoxy concrete alone.

	
steel specimens exposed to radiation	Concrete specimens exposed to radiation

	
Exposure of iron specimens to DBA	Exposed concrete specimens to DBA

Zinc oxide used in protective coatings is zinc coated with epoxy silicate. Considering this, it can be assumed that the degree of reaction between zinc and sodium borate solution will vary depending on the water resistance of the epoxy silicate surrounding the zinc and the dispersion of the zinc.

5. Conclusions

In this paper, we have investigated the degradation mechanisms of zinc and epoxy in nuclear power plant design basis accidents. We believe that degradation is more likely to occur in zinc than in epoxy. Therefore, when applying zinc coating on steel surfaces, an epoxy layer should be applied on top of the zinc, with high-quality application at the recommended film thickness by the manufacturer.

REFERENCES

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