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Safety Assessments of RCS Zinc Injection to Reactor's Primary System

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Zinc injection to the reactor's primary system has been performed since mid 1990's for overall primary water chemistry program, material management(mitigation of primary water stress corrosion cracking, PWSCC), and a dose reduction program for utilities to optimize core design, address primary system material issues, and minimize dose impact on plant personnel. Additional information from researches conducted in nuclear power plant site has proven that the zinc injection is effective in managing radiation in the plant and in PWSCC field.

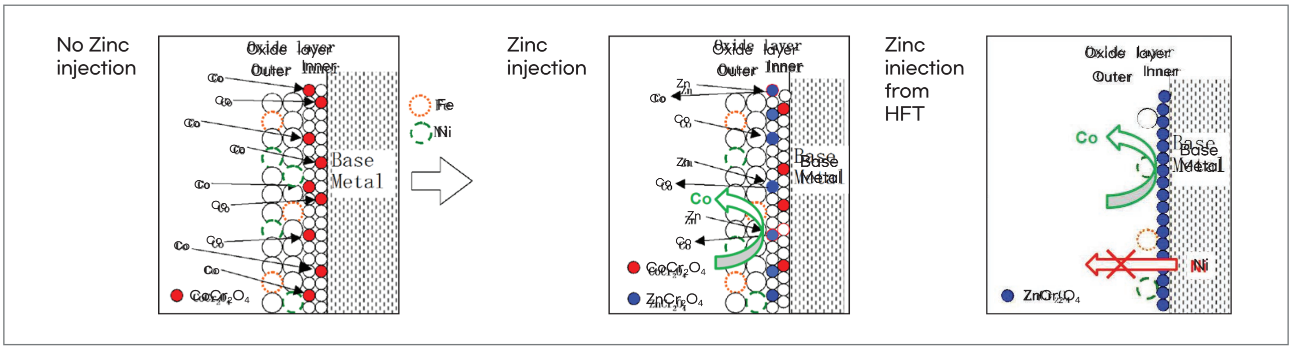
Description

● Background

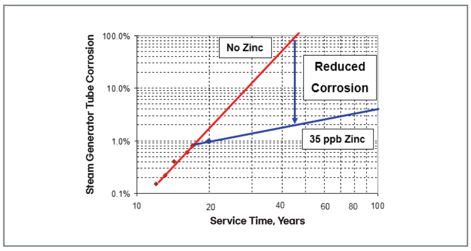
- Corrosion products(mostly oxides of nickel and iron as well as elements in solution) are released from various places in the primary system of nuclear power plants(or reactor cooling system, RCS), particularly from the steam generators then these products circulate through the coolant in core. Corrosion products can be released or deposited on all surfaces, these are referred to as "Crud".
- Rise of Crud deposition increases the risk of crud Induced Power Shift(CIPS) or crud induced localized corrosion(CILC). CIPS occurs when the crud deposits become sufficiently extensive and subcooled boiling rates are sufficiently high to result in precipitation of significant amounts of lithium-boron compounds within the crud layer. This results in a shift in axial power distribution regardless of boron-itself deposition. Locally, thick crud deposits can also reduce thermal conductivity and increase fuel clad temperature. This can lead to CILC phenomenon.

● Purpose and Necessity

- The fuel rod cladding provides the primary barrier against the release of radioactive fission products produced during the operation. Maintaining cladding integrity is a primary objective for the plant operator and the licensing authorities. Therefore, new operating environments/conditions like a zinc injection are introduced and implemented by a thorough safety evaluation process.
- Zinc injection to primary system can reduce the radiation exposure dose and mitigate



PWSCC, and the reduced corrosion rate in the long-term could reduce the cause of fuel crud that has contributed to issues associated with PWR fuel performance. However, since there is a risk of short-term increase in crud due to zinc injection, an appropriate core safety evaluation shall be conducted for each plant and cycle prior to the injection.



< Corrosion Reduction in Steam Generator Tube >

● Principle

- One concern associated with Zinc injection to Light Water Reactor is the possibility of Zinc oxide or Zinc silicate depositing inside the crud on the core. Such deposition could decrease heat transfer through porous crud or increase fuel cladding corrosion. In addition, boiling concentration in crud can lead to zinc concentration above the solubility criteria of Zinc oxide or Zinc silicate.
- The minimum solubility of ZnO at pH 6-8 is approximately 170 ppb in a wide range. Thus, for a plant injecting Zinc with 20 ppb, a concentration factor needed to precipitate Zinc is about 9. The connection between the crud thickness and mass evaporation rate to concentration factor is not determined. Zinc silicate(Zn2Si04, Willemite) is another Zinc compound that may be found in fuel tube. Like ZnO, it has never been observed in PWR fuel deposits, but it has been identified in PWR secondary side deposits and in BWR deposits. A thermodynamic calculation shows that Zinc silicate is less likely to precipitate than Zinc oxide at typical reactor coolant Silica levels of 1 ppm and less. However, low levels impurities in the coolant such as Aluminium, Calcium or Magnesium could lower the solubility of zinc causing more complex Zinc silicate compound precipitation. A firm basis for the limits that have been imposed on these impurities needs to be established.

● Work Scope

- To assist utilities in the application of Zinc injection to the reactor coolant, KEPCO NF wlil perform the followings.
  - Impact Assessments/evaluation of fuel and core design(including fuel integrity and performance)
  - Impact Evaluation of safety analysis (LOCA/Non-LOCA)
  - Reactor coolant monitoring requirement setting (fuel supplier scope) and reviewing/ commenting to operational procedure(if necessary)
  - Develop an CIPS contingency guidelines during operation
  - Measure the oxide thickness and/or clean fuel with ultra-sonic(if requested)

Distinctiveness

- KEPCO NF provides the best available results with the lastest technology and corresponding to the customer's demand.
- The service also includes an detailed impact analysis of Zinc exposure for commissioning phases(HFT and PAT)

Experience

● Republic of Korea,

- Mostly in matured plants such as WEC 3-Loop plants and OPR1000s : 16 units including Hanul unit 1(since 2010), Kori unit 3(since 2016), Hanbit 3(since 2017), others are in the process

● Overseas

- More than 30% of matured plants : Farely unit 2(since 1994)
- New plants from HFT : Tomari unit 3(2008), Watts Bar unit 2(2016), Haiyang(2016), Barakah units 1~4(since 2019*)
- New plants from cycle 1 operation : Angra unit 2(2000)

* Assessment & technical support by KNF

Deliverables

- Fuel and Safety Evaluation Report
- Requirements on reactor coolant monitoring (fuel supplier scope)
- Support and assistance for regulatory organization review/approval/licensing
- Cycle-specific Operational CIPS Contingency Guidelines

Technology Readiness Level (TRL)

Actual system proven through operation

Business Model

Technology Transfer

Licensing

Joint Search

Service Execution

Others