

Preliminary Calculation of CRUD Source-term With Modified Corrosion Product Transport Model for PWR Primary Circuit

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1. Introduction

Corrosion products are released from the surface of materials of the primary coolant circuit, which contacts with the coolant. These corrosion products become mixed with primary coolant due to a continuous interaction of turbulent flow with the corroded surfaces of primary coolant circuits. Corrosion products deposited on the out-of-core surface in PWR primary coolant systems, is a major source of CIPS (Crud Induced Power Shift) or CILC (Crud Induced Localized Corrosion) [1,2]. Modelling and numerical estimation of crud and corrosion product can be used to estimate the mechanism of the boron hideout during plant operation.

2. Methodology

2.1 CRUD source-term calculation

In this study, the governing equation of the reference study [3] was used for the calculation of CRUD source-term. The governing equation was calculated the molar conservation of either iron(Fe) or nickel(Ni) in coolant around the primary circuit.

$$\frac{dx_i}{dt} = \frac{\dot{m}}{\rho_{f,i}V_i}(x_{i-1} - x_i) - \frac{A_i J_i}{V_i C_i} \quad (1)$$

In order to conduct the calculation of CRUD source-term, the variables contributing to CRUD source-term clarified. The molar flux, J_i is the molar flux of iron or nickel from the bulk coolant to the

surface of the section.

$$J_i = C_{bulk}[x_{bulk}u + k_m(x_{bulk} - x_{surf})] \quad (2)$$

This equation is obtained by summing the flux equations for the component metal ions in solution. The total molar concentration in the bulk and the mole fractions of iron or nickel in the bulk and at the surface are used to calculate the molar flux.

2.2 PWR primary circuit thermodynamics

One of the important parameters contributing to CRUD source-term is the thermodynamic problem for solution species and solid phase iron and nickel compounds in the primary circuit of a PWR. In this study, we used the method of decoupling the Fe, Ni problem and the Li-B-H₂ problem. First, solve for the Li-B-H₂ mole fractions in the bulk coolant and secondly, determine the Fe and Ni mole fractions for the precipitation of solids at the surface. A numerical method which like the quasi-newton method is used to obtain mole fractions. These processes are applied to each section of the primary coolant circuit.

2.3 Corrosion release and deposition

The release of iron or nickel due to corrosion at the surface is described by the release flux [3]. The release flux is expressed by the following equation,

$$J_{release} = \frac{am_{corroded}}{At_{corroded}} \quad (3)$$

Therefore, the unit mass of metal corroded, the molecular weight and the weight fraction of atom in the alloy are required to calculate the variables on the release flux.

Precipitation of iron or nickel compounds at the surface of a section is described by the precipitation flux [3]. The precipitation flux is expressed by the following equation,

$$\frac{dM_{precipitation}}{dt} = J_{precipitation} \quad (4)$$

Which if any of the solid phase compounds are precipitated is determined by a logical sequence of test using appropriate values for the surface mole fractions of iron and nickel. The surface mole fractions of iron and nickel, the precipitation of solid phase species are required to calculate the variables on the precipitation flux. A numerical method which like the van Wijngaarden-Dekker-Brent method is used to obtain the surface mole fractions.

3. Results and Conclusion

The model was run for a complete PWR cycle in the absence of boiling on the core section. Table 1 lists the iron and nickel mass balance during the cycle. The distribution of corrosion products around the primary coolant circuit is shown in Figure 1. This shows almost all the Ni are deposited in the Steam generator, on the other hand, the Fe has mainly deposited in the core.

The result obtained with the model was the prediction of soluble iron concentrations in the coolant of a PWR in good agreement with the reference study. However, predicted nickel concentrations appeared to be low as like a consequence of reference study. This result is thought to be the inclusion of particulate in the measured value for nickel, therefore, this model will need to contain an analysis model of particulate deposition.

Table 1. Iron and nickel mass balance(without boiling)

	Metal (g)	Metal (mol)
Steel corroded	10000	179.1
Inconel corroded	20000	340.8
Fe released	3630	65.0
Ni released	12739	217.0

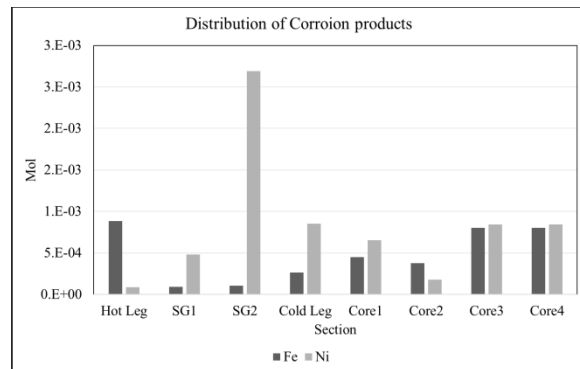


Fig. 1. Distribution of Corrosion products (without boiling).

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