Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 19-20, 2022

Radiological Methodology for Estimation of Crud Thickness in PWR Coolant System

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1. Introduction

Corrosion product (e.g. crud) deposition on fuel cladding surface is the key industrial concern that implicates the fuel performance and its reliability, caused by corrosion-induced localized corrosion (CILC) and crud-induced power shift (CIPS). Activated crud is deposited on out-of-core surfaces (e.g., steam generators), resulting in high radiation doses in the primary coolant circuit system [1–3]. Some of activated crud is released into reactor coolant system (RCS) and re-deposited in the RCS pipe, causing a radioactive contamination problem in the RCS. As a result, the radioactive crud in the RCS increases the possibility of radiation exposure of workers. Therefore, due to radiation build-up in the primary circuit systems, mechanistic understanding the crud deposition behavior at various locations of interest is necessary by considering the following key parameters such as, the deposition, residence time, and release rates. This paper summarizes the preliminary experimental approaches for measuring the weight and specific activity of crud. The thicknesses of the crud deposited at the measurement location are also calculated using the specific activity and pipe surface activity according to the previous study [4, 5].

2. Crud Analysis Methods

The crud specific activity was calculated by measuring the radioactivity and weight of the crud.

2.1 RCS Crud Activity Measurement Procedure

To calculate the specific activity of the crud in the RCS, experiments were performed according to the procedure shown in Fig. 1. The RCS samples were collected and the activity of the coolant sample was measured by using a High Purity Germanium detector (HPGe). Measurement of the weight (A) of the oven-dried filter before filtering the coolant was carried out. After filtering, the weight of the filter was measured (B), and the filtered crud weight (C=B-A) was calculated. The activity of filtered crud was measured (D), and the specific activity (*Bq/g-crud*) of the crud was calculated ($\frac{D}{C}$). The gamma measurement data should be corrected at the time of sampling.

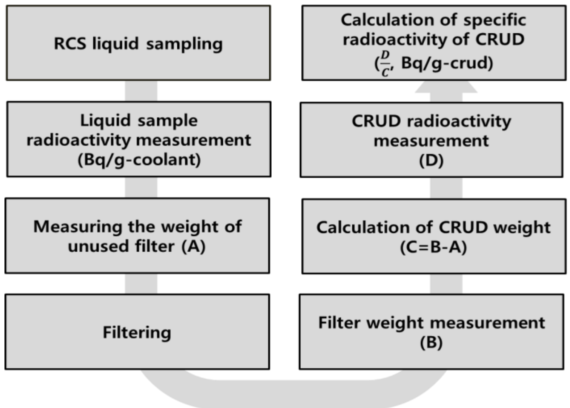

Fig. 1. Flow Chart for Crud Specific Radioactivity Analysis Experiment Sequence

2.2 Crud Weight Measurement

A nylon membrane filter having a diameter of 47 mm and a pore size 0.45 μm was used, and the coolant crud was collected using a decompression filtration device connected a vacuum pump. After drying the filter in an oven, the weight of the collected crud in the filter was measured using a precision scale.

2.3 Crud Specific Activity Measurement

The standard source (a 47 mm diameter paper filter dry source) was prepared and the energy and efficiency of the gamma measurement program was calibrated. The specific activity value was derived by dividing the total activity of the crud by the measured crud weight.

3. Results

3.1 Crud Weight

The crud weight(C) can be measured through coolant filtering, and in this study, the average crud weight of 75 μg as presented in the FSAR [5] was used.

3.2 Crud Specific Activity

The specific activity was derived by dividing the crud activity for each nuclide by the crud weight. Table I shows the specific activity calculation results of long-lived nuclide (Co-58, Co-60, Mn-54, Zr-95, Fe-59) constituting crud.

Table I: Specific Activity of Long-lived Radionuclides

Nuclide	RCS Crud activity (*Bq*)	Crud weight (μg)	Crud specific activity (*Bq/g-crud*)
Co-58	1.33E+05	75	1.77E+09
Co-60	4.67E+05		6.22E+07
Mn-54	1.49E+03		1.99E+07
Zr-95	3.68E+03		4.90E+07
Fe-59	3.14E+03		4.18E+07

3.3 Crud Thickness

Fig. 2 shows the radiological crud thickness measurement methodology. The thickness of the crud is calculated by dividing the surface activity (*Bq/cm*^{2}) for each nuclide, which is the In-Situ Object Counting System (ISOCS) measurement results, by the specific activity (*Bq/g-crud*), and it can be calculated as follows:

$$Crud\ thickness(\mathrm{g}/cm^2) = \frac{Surface\ activity\ (\frac{Bq}{cm^2})}{Specific\ activity\ (\frac{Bq}{g-crud})} \quad (1)$$

Specific activity should be calculated by collecting coolant before overhaul (OH) of the target unit, and surface activity should be measured within 7 to 14 days after OH.

Table II shows the surface activity presented in the previous study [4], and the average value of the radiological crud thickness divided by the specific activity of FSAR. These results are similar to 1.00E-03 *g/cm*^{2}, which is the value of the equilibrium crud film thickness of Vessel, Internals, Piping, and SG Inlet Plenum deposited in the RCS in the FSAR [5].

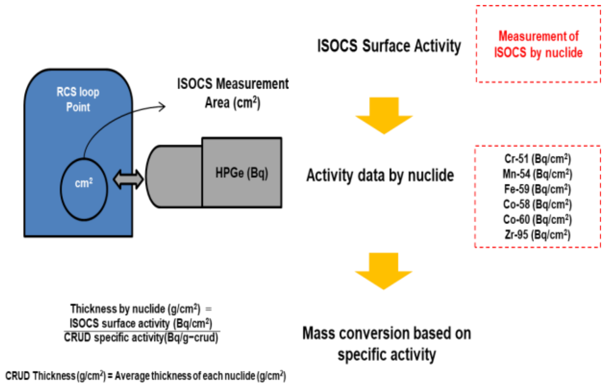

Fig. 2.Radiological Crud Thickness Assessment Methodology

Table II: Radiological Crud Thickness

	Nuclide	Dukovany Unit 1 [4]	Dukovany Unit 2 [4]
ISOCS surface activity (*Bq/cm*^{2})	Co-58	1.10E+05	2.10E+05
	Co-60	2.00E+04	5.00E+03
	Mn-54	1.00E+03	5.00E+03
	Zr-95	1.00E+04	5.00E+03
	Fe-59	5.00E+03	5.00E+03
Average Crud thickness (*g/cm*^{2})	FSAR	1.52E-04	2.47E-04
	FSAR [5]	1.00E-03	

4. Summary

The activity and weight of the crud can be measured though the filtration of the coolant sample and the specific activity of the crud can be derived. The radiological crud thickness was calculated using radiological approaches with the specific activity and surface activity data. Preliminary results indicate that the radiological tool is a good methodology for estimating the crud thickness. In the future, the radiological crud thickness for each plant will be derived by direct measurement of the surface activity, crud weight and crud specific activity at sites.

Acknowledgment

This work was supported by the Korea Hydro & Nuclear Power Co., Ltd (KHNP) Central Research Institute grant funded by KHNP (No. L21S035000).

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