Validation of the POSCA Code Using the COMEDIE BD-1 Experiment

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1. Introduction

In a high temperature gas-cooled reactor (HTGR), once the fission products are released from the fuel into the coolant, they are transported throughout the primary circuit by the flowing helium coolant. Many fission products are removed by the purification system. In the case of some condensable fission products such as I-131 and Cs-137, however, more dominant mechanism is deposition on various helium-wetted surfaces in the primary circuit (i.e., the deposition rate far exceeds the purification rate) [1]. The deposited activity is referred as plateout activity. The plateout activity may be built up high over long periods of reactor operations. Therefore, the fission product plateout is the one of the key considerations for the design of a HTGR. It was nominated as one of the most significant phenomena (those assigned an importance rank of "high" with the corresponding knowledge level of "low or medium") in the fission product phenomena identification and ranking tables (PIRTs) of the next generation nuclear plant (NGNP) [2].

Korea Atomic Energy Research Institute (KAERI) has been developing a new computer code named POSCA (Plate-Out Surface and Circulating Activities) [3-4] to predict fission product plateout and circulating coolant activities under normal operating conditions of a HTGR. The existing works [3-4] focused on the verification study of the POSCA code using analytic benchmark examples. This paper presents a validation work of POSCA using a well-known experiment, COMEDIE BD-1.

2. COMEDIE BD-1 Experiment

The COMEDIE BD-1 experiment was carried out by France CEA in 1992 under the US Department of Energy (DOE) sponsorship to obtain experimental data to validate the design methods used to predict fission product release from the TRISO fuel and plateout in the primary coolant circuit of a HTGR [5-6]. It was performed in the SILOE material test reactor in Grenoble, France. Fig. 1 shows the general assembly of the COMEDIE loop and the major test parameters are provided in Table I.

A prismatic fuel block was installed in the in-pile section. It contained fuel compacts seeded with "designed-to-fail" TRISO particles. A straight tube gas-to-gas heat exchanger comprised of three parallel bundles (named U, V, and W) was used to cool the helium coolant. Fig. 2 shows the heat exchanger adopted in the COMEDIE BD-1 experiment. Downstream of the heat exchanger was a full-flow filter to trap condensable radionuclides including circulating particulates.

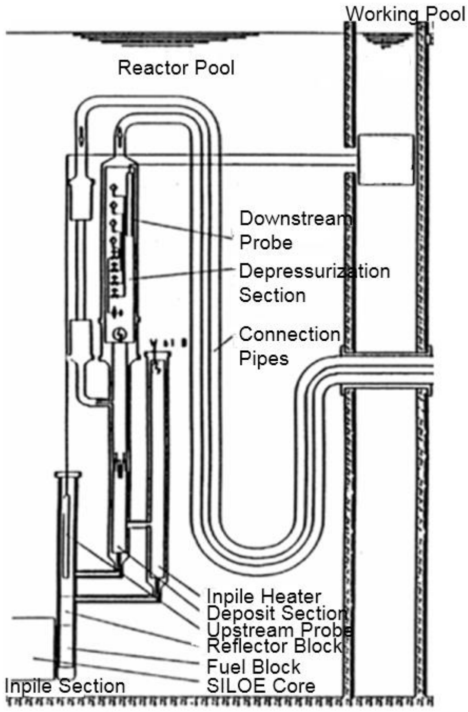

Fig. 1. COMEDIE facility [6].

Table I: Major Test Parameters of COMEDIE BD-1 Experiment [6]

Parameter	Nominal value
Loop power	30 kW
TRISO fuel particle	LEU UCO
Primary coolant	helium
Thermal neutron flux	~10^{17} n/m^2-s
Max. fuel temperature	1250~1350 ^{o}C
Test duration	63 days
Coolant flow rate	38 g/s
Purification flow rate	0.3 g/s
Coolant temperature	200~880 ^{o}C
Primary coolant pressure	60 atm
Reynolds number (in HX)	> 5000
HX inlet/outlet temp. (primary)	720/300 ^{o}C

3. POSCA Model

Fig. 3 shows the POSCA model to simulate the COMEDIE BD-1 experiment. The returning loop after the heat exchanger was neglected because it was assumed that the fission products are completely removed by the purification filter. Fig. 4 provides the temperature distribution along the heat exchanger tube.

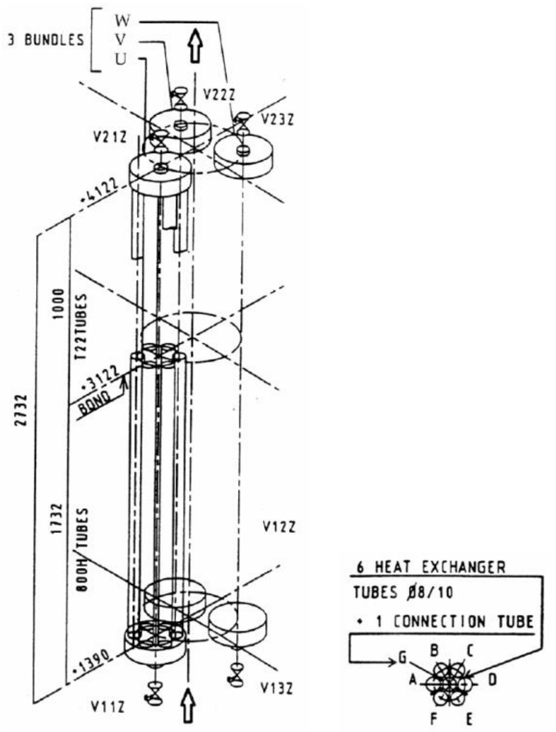

Fig. 2. Heat exchanger adopted in COMEDIE BD-1 [6].

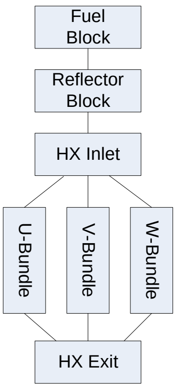

Fig. 3. POSCA model to simulate COMEDIE BD-1.

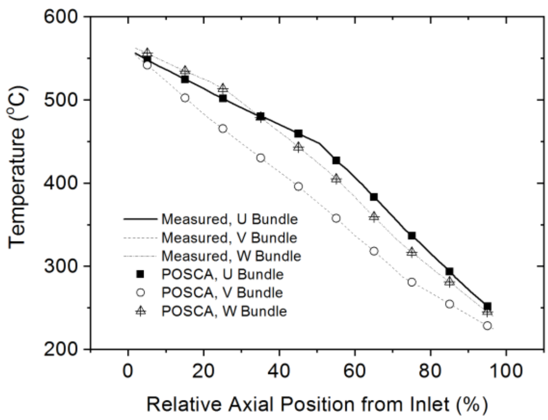

Fig. 4. Temperature distribution along the heat exchanger of COMEDIE BD-1.

The source generation rate of fission products into the coolant was indirectly estimated and used for the boundary conditions of the POSCA calculations. For I-131, Cs-137, and Ag-110m, the total amount of the measured activity for the entire loop was used whereas the measured activity for the heat exchanger tubes was used for Te-132.

The sorption model developed by the General Atomics (GA) [7] was applied for I-131, Cs-137, and Ag-110m. On the other hand, the perfect sink plateout model was used for Te-132. It was assumed that the structural surfaces were oxidized.

4. Validation Results and Discussions

Figs. 5 ~ 8 show the validation results of the POSCA calculations for I-131, Cs-137, Ag-110m, and Te-132, respectively. The reported results by the PADLOC code developed by GA [6] are added for a comparison.

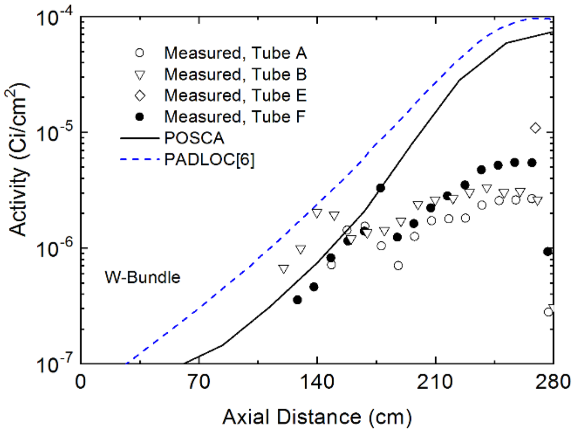

Fig. 5. Validation of POSCA using I-131 measurement.

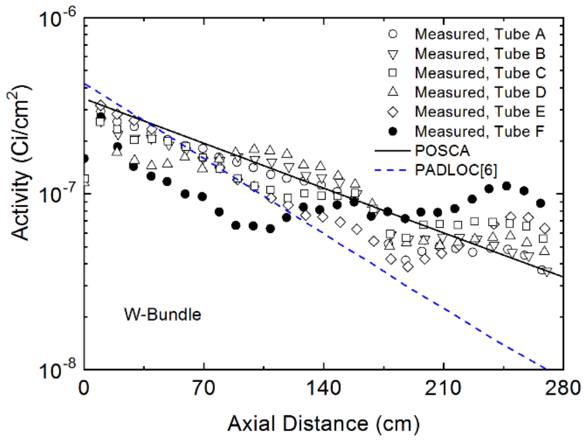

Fig. 6. Validation of POSCA using Cs-137 measurement.

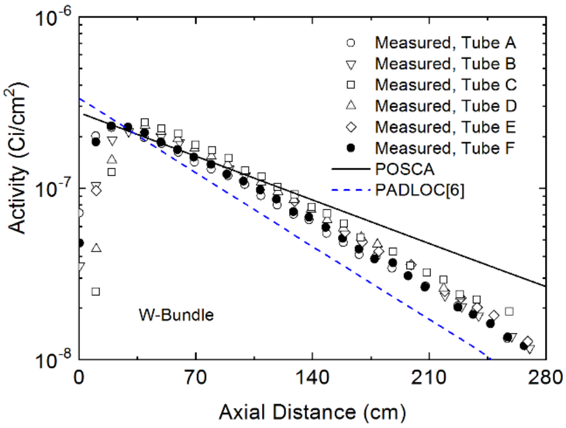

Fig. 7. Validation of POSCA using Ag-110m measurement.

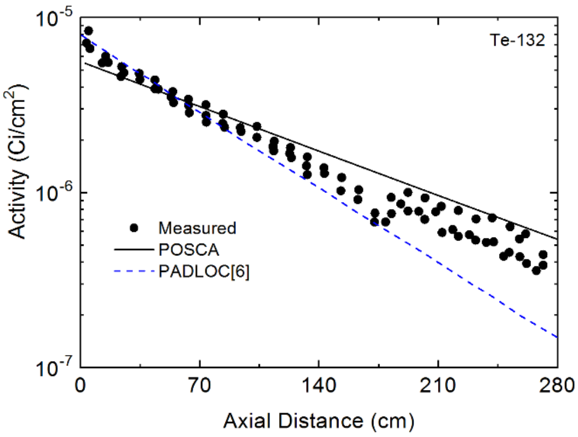

Fig. 8. Validation of POSCA using Te-132 measurement.

It can be seen that the accuracy of POSCA is comparable to PADLOC. Except I-131, the overall differences between the predicted and measured values are less than one order of magnitude (=target accuracy of the plateout codes [1]). POSCA as well as PADLOC over-predicts the plateout activity of I-131 at the lower temperature region. The prediction is slightly beyond the target accuracy. An improvement is required for the iodine prediction. For a perfect sink plateout, the plateout profile should be a straight line on a semi-log plot, and the negative slope is inversely proportional to the mass transfer coefficient. Fig. 8 shows that POSCA reasonably simulates a perfect sorption behavior.

It was confirmed that the POSCA calculation is very fast. The running times to simulate 63 days of the COMEDIE loop were less than 1 minute.

5. Conclusions

In this paper, the validation of the POSCA code using the COMEDIE BD-1 experiment was carried out. The results of the validation show that the numerical model of POSCA is reasonable and its accuracy is comparable to the famous code, PADLOC. An improvement on I-131 prediction is required to achieve the target accuracy of the plateout code. Such improvement is very challenging. It should be noted that no plateout codes in the world are satisfied with the target accuracy at the moment [1]. Further validation studies are required for practical applications to HTGR designs. In particular, the CMVB (Computational Methods Validation and Benchmarks) of the Generation IV international cooperation would be fruitful in the verification and validation of the POSCA code.

Acknowledgements

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (No. 2017M2A8A1014757).

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