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Simulation of COMEDIE Fission Product Plateout Experiment Using GAMMA-FP

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1. Introduction

Fission product plateout has been considered as crucial phenomenon during the transport process of fission products under normal operating as well as accidental conditions [1]. This phenomenon is particularly important under a VHTR design with vented low pressure confinement (VLPC), because the vent allows the prompt release of fission products accumulated within the primary circuit to environment during an initial blow-down phase after pipe break accidents. In order to analyze the fission product plateout, an numerical model was developed by Yoo et al. and incorporated into the GAMMA-FP code [2,3] in the past. The GAMMA-FP model was validated against two experiment data, i.e., VAMPYR-1 and OGL, during the development phase.

One of the well-known experiments for fission product plateout is the COMEDIE experiment [4,5]. In this work, the COMEDIE experiment has been simulated using the GAMMA-FP code to investigate the reliability and applicability of the plateout model of GAMMA-FP.

2. COMEDIE Experiment

The COMEDIE loop was an inpile test facility in the SILOE material test reactor in Grenoble, France. The general assembly of the COMEDIE loop is shown in Fig. 1. The COMEDIE experiment was conducted by CEA from September 3 to November 26, 1992 under the US Department of Energy (DOE) sponsorship to obtain integral test 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 prismatic gas cooled reactor. The major test parameters are summarized in Table I.

The inpile section included a prismatic fuel block which was the source of fission products. The fuel block contained fuel compacts seeded with “designed-to-fail” low enriched uranium UCO TRISO particles. Graphite reflector block was placed at the downstream of the fuel block. The reflector block was followed by a straight tube gas-to-gas heat exchanger which was comprised of three parallel bundles. Each bundle contained six tubes carrying coolant helium. Downstream of the heat exchanger was a full-flow filter to trap condensable radionuclides including iodine and circulating particulate matter.

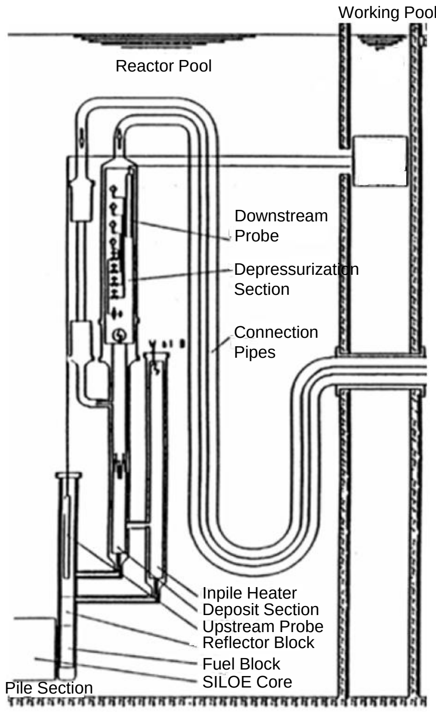

Fig. 1. General assembly of the COMEDIE loop [5].

Table I: Major Test Parameters of COMEDIE experiment [5]

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. Method and Results

The GAMMA-FP model to simulate the COMEDIE experiment is shown in Fig. 2. It considers the complete COMEDIE loop in terms of fission product plateout. The sorption model of the General Atomics [2] was applied and oxidized structural surface was assumed for the calculation.

During the GAMMA-FP preliminary calculations, it was found that it takes too much time (e.g., 383 hours) for the simulation of 63 days which is the entire duration of the COMEDIE experiment. This was mainly resulted from small time step size (e.g., order of millisecond) which was determined by the fluid conditions. Therefore the solution scheme of Yoo et al. was modified in this work to allow a separate time step size for fission product analysis after the fluid conditions reached the steady-state conditions. Table II shows the effect of the time step size change. The results were obtained from a preliminary model. It shows that smaller calculation time can be achieved using larger time step size for fission product analysis. However, the time step size for fission product analysis must not be increased too much (e.g., beyond 0.1s in Table II) because the fractional step method adopted in GAMMA-FP results in larger numerical errors for larger time step size.

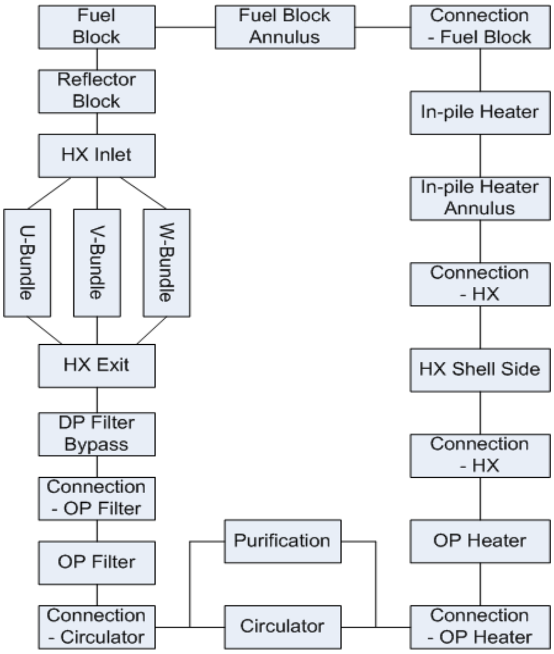

Fig. 2. GAMMA-FP model to analyze the COMEDIE experiment.

Table II: The Effect of Time Step Size

	Calc. Time (hr)	Calculated I-131 Deposition (atoms/m^2)
Original (same Δt)	383	1.05E+16 (ref.)
FP Δt = 0.001 s	143	1.05E+16
FP Δt = 0.005 s	48	1.05E+16
FP Δt = 0.1 s	54	1.01E+16
FP Δt = 0.5 s	63	8.65E+15
FP Δt = 2.0 s	67	5.21E+15

Figs. 3 & 4 show the measured and predicted plateout activities of I-131 and Cs-137, respectively. The selected location is the heat exchanger bundle W which is comprised of six tubes (A~F). Since the release rate of the nuclide from the fuel to the coolant was not available, the source term to the coolant was indirectly estimated based on the measured value of the total plateout activity along the loop. In spite of some uncertainties of the applied source term, a good agreement is shown between the measured and predicted values.

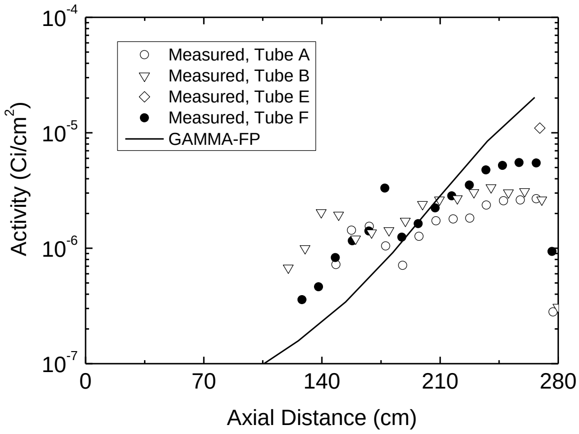

Fig. 3. Measured and predicted I-131 plateout profiles.

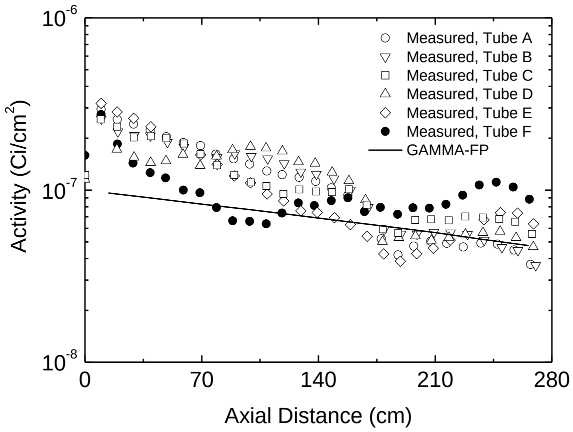

Fig. 4. Measured and predicted Cs-137 plateout profiles.

4. Conclusions

The COMEDIE experiment for fission product plateout was simulated using the GAMMA-FP code in this work. A good agreement was achieved between the measured and predicted plateout activities. The existing solution scheme was modified to allow larger time step size for fission product analysis in order to speed-up the computational time. Nevertheless, the modification of the existing numerical model of GAMMA-FP is necessary when a simulation capability of a long duration of plateout period (e.g., 60 years) is targeted.

Acknowledgements

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REFERENCES

[1] IAEA, Fuel Performance and Fission Product Behavior in Gas Cooled Reactors, IAEA-TECDOC-978, 1997.
[2] J.S. Yoo, N.I. Tak, H.S. Lim, J.H. Chun, "Numerical prediction of the fission product plate-out for a VHTR application," Ann. Nucl. Energy, Vol. 37, p. 471, 2010.
[3] J. S. Yoo, N.I. Tak , H.S. Lim, "Numerical Analysis of the Fission Product Plate-Out Distribution in the VAMPYR-I Experiment," Transactions of the Korean Nuclear Society Autumn Meeting, Gyeongju, Korea, October 29-30, 2009.
[4] R. Gillet, D. Brenet, D.L. Hanson, O.F. Kimball, COMEDIE BD1 Experiment: Fission Product Behaviour During Depressurization Transients, Design and Development of Gas-cooled Reactors with Closed Cycle Gas Turbines, IAEA Technical Committee Meeting, Beijing, 1995.
[5] D.L. Hanson and A. A. Shenoy, "Inpile Loop Tests to Validate Fission Product Transport Code," Proceedings HTR2006: 3rd International Topical Meeting on High Temperature Reactor Technology, Johannesburg, South Africa, October 1-4, 2006.