TROPY Code Verification and Validation on Tritium Inventory in a High Temperature Gas cooled Reactor

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1. Introduction

High Temperature Gas cooled Reactor (HTGR) has been studied as one of the Gen-4 reactors in Korea Atomic Energy Research Institute (KAERI). The HTGR has many benefits by using a high temperature gas coolant. The high temperature coolant might be used for the Brayton cycle, the process heat and hydrogen production. Moreover, the HTGR might remove a decay heat with only natural air circulation under an accident event. Various studies on the reactor core have been conducted to find a safe and optimized design. However, the study on fission product (FP) behavior is not yet sufficient for practical application to HTGR designs. There are numerous FPs in the reactor core of HTGR. Many codes on the FPs adopt FP grouping by characteristics to reduce computational time. But, a tritium in the core is solved usually independently because the tritium does not have decay chain reaction and is important to analyze a behavior during normal operation due to leakage and permeation. As a result, an independent analysis code has been developed in each country. JAERI has developed THYTAN[1] to analyze the tritium transport in system. Idaho National Laboratory (INL) has developed the Tritium Permeation Analyses Code (TPAC)[2] using the MATALAB S/W. KAERI has been developing Tritium Overall Phenomena analysis(TROPY) to predict the tritium production and transport in system[3]. Previous TROPY version was modeled with zero dimensional equations. Therefore, there was limitation to construct flexible loops including secondary systems and/or hydrogen production facility. Thus, the TROPY code was improved using one dimensional model. On the present paper, the verification calculations are written for the improved version of the TROPY code.

2. Methods and Results

The TROPY code has been under development to analyze the tritium production, sorption, leakage and permeation in the HTGR system. The main parameters modeled in the TROPY code are as following

- Production
- Bound
- Recoil
- Leak
- Permeation
- Chemi-sorption
- Purification
- Isotope exchange in SI system

2.1 Modeling

The tritium distribution in the system of Fig. 1 is obtained by the following one dimensional equation.

$$\frac{\partial C_i}{\partial t} = \dot{q}_{c,i} + \sum_{j=1}^{N_T} a^*_{i,j} C_j - \frac{1}{A_F}\frac{\partial}{\partial x}(A_F v C_i) \quad (1)$$

C_i is atoms/m^3, $\dot{q}_{c,i}$ is tritium source by production, release, permeation and so on. v is flow velocity and A_F is the flow area. $a^*_{i,j}$ means loss by decay, leak, purification and permeation.

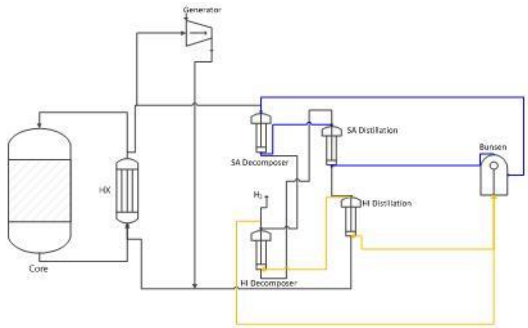

Fig. 1. Schematic of HTGR system

2.2 Verification

The developed TROPY code was verified with the results of GA calculations for a MHTGR350 core.

The boundary condition in the MHTGR350 is summarized in Table I.

Table I: MHTGR350 design parameter

Reactor power[MWt]	350
Primary coolant weight[kg]	2948.35
Primary coolant pressure[MPa]	6.3
Average coolant temperature[C]	471.5
He-3 abundance [fraction]	2.E-7
Helium replacement [1/sec]	3.17E-9
Helium purification [1/sec]	9.5E-4

The reactor core of MHTGR350 consists of active core 1, active core 2, top reflector, bottom reflector, inner reflector, side reflector and control rods. The chemisorption on the graphite block was calculated by using MYER's model[4]. Total operation period is 42 years. Table II shows the calculated results for first three cycles. The calculated data by the TRITGO code (zero dimensional code of analytic solution) were also compared in the present study.

Table II: Tritium distributions for first three cycles

H-3	EOC1 (Curies)		
	GA	TRITGO	TROPY
Production	8.78E3	8.779E3	8.82E3
Bound in Solids	2.E3	1.995E3	2.008E3
Adsorb	7.6E2	7.584E2	7.856E2
In primary	7.44E-2	7.45E-2	7.47E-2
H-3	EOC2 (Curies)		
	GA	TRITGO	TROPY
Production	1.3E4	1.294E4	1.29E4
Bound in Solids	3.813E3	3.813E3	3.822E3
Adsorb	1.17E3	1.16E3	1.2E3
In primary	3.65E-2	3.64E-2	3.76E-2
H-3	EOC3 (Curies)		
	GA	TRITGO	TROPY
Production	1.57E4	1.56E4	1.56E4
Bound in Solids	5.47E3	5.469E3	5.481E3
Adsorb	1.46E3	1.44E3	1.49E3
In primary	2.44E-2	2.44E-2	2.59E-2

Fig. 2, 3 and 4 represent tritium inventory and remain in primary loop and secondary loop during normal operation. Each calculated data well agree. The tritium in the primary loop does not exceed the design limit by the calculation.

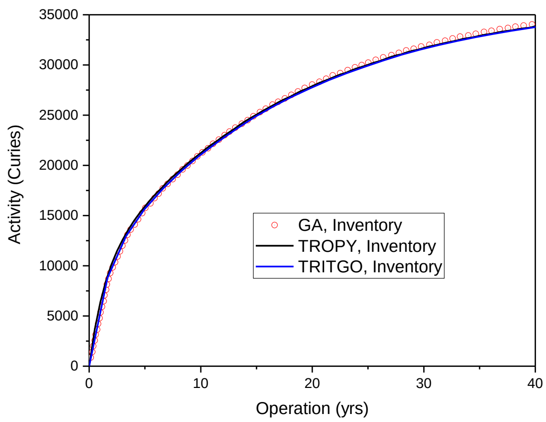

Fig. 2. Tritium inventory verification

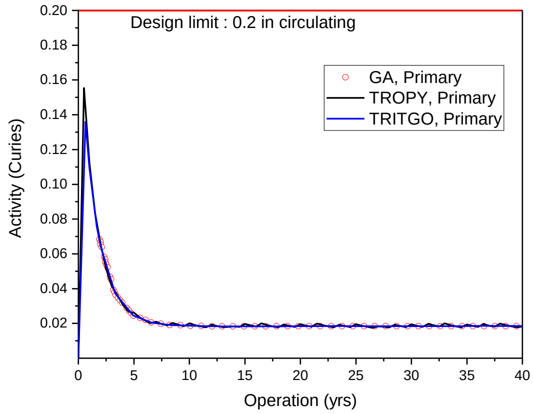

Fig. 3. Tritium in primary coolant

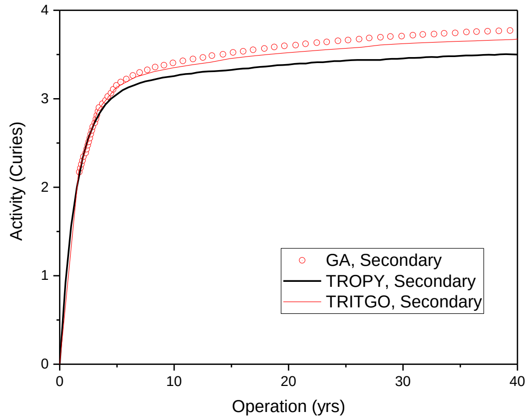

Fig. 4. Tritium in secondary coolant

The TROPY code also was validated with the reported values in the Peach Bottom reactor [5]. The reported values after 4 year operation and the calculated data by THYTAN[1] and TROPY are written in Table III.

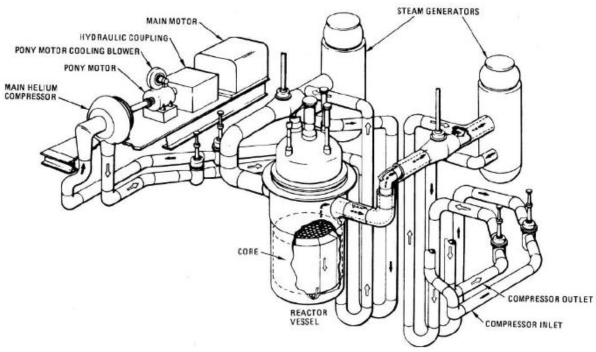

Fig. 5. Primary coolant system of the Peach Bottom[5]

Table III: Tritium inventory in Peach Bottom

H-3	Reported[5] [Bq]	THYTAN[1] [Bq]	TROPY [Bq]
Ternary Fission	4.43E13	4.42E13	4.43E3
Li-6	2.66E12	2.7E12	2.66E12
He-3	2.40E12	2.72E12	2.25E12
B10	3.17E12	3.18E12	2.97E12

3. Conclusions

The TROPY code has been developed with one dimensional modeling and verified with the existing data. The tritium inventory in the core was well match with the calculated data by GA code. By the calculation, the tritium amounts in the primary do not exceed the design limit during normal operation. The TROPY code was also validated with the reported value of Peach Bottom reactor. The calculated data by TROPY well agree with the reported value as well as the calculated data by THYTAN code. The developed code will be used to analyze the tritium distributions in the plant system including hydrogen production system after more verification studies.

Acknowledgements

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